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REPORT ON THE PLACUNA PLACENTA PEARL FISHERY OF LAKE TAMPALAKAMAM.

With one plate and two sketch-plans.

By JAMES HORNELL, F.L.S.

THE beginning of a long deferred biological survey of Lake Tampalakamam was made in May of this year; before proceeding to detail the results obtained with regard to the present condition of the *Placuna* pearl beds which give this bay its local importance, it will be well to furnish some particulars of the principal topographical and physical peculiarities of the locality in question, together with what few notes I have been able to gather regarding the history of the Tampalakamam pearl fishery.

The time and means at my disposal did not permit the making of an exhaustive collection of the fauna and flora, but the detailed knowledge gained of the topography of the lake will greatly facilitate further work, for, as has been my usual experience in Ceylon, the best charts and plans available for out-of-the-way places are miserably inadequate when identification of landmarks is requisite; the makers of such charts as I have had to use appear to have been remiss beyond belief in this essential of good cartography, for in the comparatively few cases where names are attached to places of topographical value they are, as a rule, rendered incorrectly. Who, for instance, can recognize Periya-ar in Kerni-aru, Semmalai in Chamaimalai? After this we think nothing of finding Nachchikuda masquerading as Narche Coudar, Kakamunai as Corkamunny, and Malay Cove as Maly Cove.

Most of these initial topographical difficulties I have smoothed out, and the attached sketch plan of the lake (Annexure III.) will, I hope, enable my notes to be followed with comparative ease.

When the faunistic collections are completed they will be distributed to specialists in the different groups to be reported upon in detail.

I.—TOPOGRAPHY AND PHYSICAL CHARACTERISTICS OF LAKE TAMPALAKAMAM.

Tampalakamam Lake, usually corrupted into Tamblegam Lake or Bay, is a shallow, land-locked tidal bay of great extent opening by a narrow neck-like mouth to the sea on the west side of Great Bay, Trincomalee. It lies south-west of the harbour of Trincomalee, separated therefrom by a tract of densely wooded hilly ground channeled by ravines, which in a few instances widen into short stretches of low-lying land.

The main axis of the lake lies in a north-east and south-west direction and measures 4¼ nautical miles. The breadth varies from one to two miles, the greatest width being midway between the two extremities. In general outline the lake, if shorn of the seaward entrance and the branch inlet of Nachchikuda adjoining thereto, is roughly that of a parallelogram set south-west and north-east, the entrance and Nachchikuda being at the south-east angle.

Three main divisions may be made out—an *eastern*, comprising the mouth and the northward-running inlet of Nachchikuda; a *south-western*, comprising the whole of the bag-like or cæcal western

end, separated from the central division by an arbitrary line connecting the headland of Peyaddaimunai on the north shore with Kakamunai on the south. The third or *central region* lies between the line named on the west and the mouth of Nachchikuda on the east.

Except in the channel near the entrance and in the mouth of Nachchikuda, the bottom is remarkably level, maintaining a depth of from 6 to 9 feet over the whole area, save as one approaches the shore and over well-marked banks or *kallams* which rise here and there close to the surface. Immediately within the mouth of Nachchikuda we have, however, depths from 3 to 3¼ fathoms. Generally the lake is slightly deeper off the north shore than off the south and south-west shores, where open the chief rivers and streams falling into the lake; off the mouths of several we have distinct sand spits formed; the principal is the long cockle-bearing sandbank that stretches far into the lake in a north-west direction from the mouth of the Periya-ar.

The principal streams emptying into the lake taken in order from east to west on the south shore are: Katti-ar, Periya-ar, Sembian-ar, Polokarai-ar, Periya Palamput-ar, and Tampalakamam-ar, the three latter opening through a maze of mangroves.

Along the north-west stretch of shore we have only the Sinna Palamput-ar and the Manal-ar; the latter, which is called Coppotary-ar (Kapalturai-ar) on the Admiralty chart, is of little importance.

No other streams and but a few small creeks break the line of the north-east shore and that of Nachchikuda.

The whole of the great south-west pocket of the lake, into which open the two Palamputs and the Tampalakamam-ar, is shut in by a low deep-green wall of mangroves straddling out into the shallows on grotesque stilt-roots. The north coast is generally higher than the south, and with a backing of stately hills and a diversified array of forest trees and jungle in the foreground, its appearance is picturesque and attractive—a pleasing contrast to the dark and stagnant swamp land on the opposite margin, hidden beyond which, however, there stretch miles of fertile paddy fields supporting a considerable and industrious population.

The general bottom of the lake is a dark grayish-black mud, known as *mei seru* or "ink mud," intermixed in places, and towards the shore generally, with more or less quartzose sand. True sand banks, almost or entirely dry at low water, occur in various places, and are known as *kallams*.

Among the more noteworthy of these are *Muttikallam* and *Amaikallam* lying between the Sinna Palamput-ar and Peyaddaimunai on the one hand and Kakamunai on the other; *Muttikallam* is a sand-bank awash at low water and the home of edible shellfish (*Mutti*, Tam., a general term embracing *Cardium*, *Venus*, and other cockles and clams), while *Amaikallam*, the "Turtle Bank," characterized by a fairly uniform depth of half a fathom, bears abundance of vegetable life (Algæ and *Halophila*), and thereby is a favourite resort or feeding ground for the turtles of the neighbourhood.

The place names of the lake are almost entirely all descriptive of some natural or physical characteristic—commonplace in the extreme. As instances in point, we have *Semmalai*, the Red Hill; *Vellai Kalumunai*, White Stone Point; *Serukuda* or Muddy Bay, and *Kannamunai*, a promontory where Kanna trees are abundant.

The name of one spot has a minor historic interest—Kapalturai, literally "Ship Harbour." The vicinity of this place is a good locality for snipe shooting, and in consequence it used to be a well-recognized rendezvous for shooting parties from the men-of-war stationed or calling at Trincomalee.

As is to be expected from the configuration and shallowness of the lake, the temperature of the water rises rapidly during the day; during the period of my last visit, May 18th to 24th, while the temperature varied from 82° to 82½° F. at 5 A.M., by noon it attained 89° F., falling to 88° and even 85° F. by 4 P.M., according to the strength of the cold wind from the inland hills to the south-west that prevailed at this time of day.

The air temperature in the shade varied from 82° F. at 5 A.M. to 88° and 89° F. at noon, falling to 86° and 86½° F. at 4 P.M.

On February 11, 1902, the temperature of the lake was 80° F. at 9 A.M., while when I visited it in the October following it ranged from 87° to 90° F. between 10 A.M. and noon. The general average for noon may be taken as approximating to 88° F. throughout the whole year.

The salinity of the lake is not so low as might be expected, ranging from 1·015 in the western section, where a considerable volume of fresh water is emptied into the lake, to 1·019 in the eastern division and in the median part of the central section, at temperatures from 86° to 90° F. These figures are however for the dry season; it will be necessary hereafter to make a study of the conditions which prevail during the wet season of November, December, and January and of the effect then produced upon the inhabitants of the lake.

II.—The Nature of the Placuna Pearl Fishery of Lake Tampalakamam.

The shell which furnishes this unique pearl fishery is *Placuna placenta*, L., a peculiar Lamellibranch mollusc excessively compressed laterally and furnished with white translucent valves, discous in outline. The valves are asymmetric, the left being very slightly convex, while the right is quite flat. It possesses no relationship with the true pearl oysters (Aviculidæ), being closely akin to the strange Horse-shoe oyster (*Anomia ephippium*) of British waters. But whereas *Anomia* lives firmly attached to rocks and shells by a calcified byssus passing through a circular and median aperture in the right valve, *Placuna placenta* has no byssus in adult life and lives free, preferring as its chosen habitat the muddy flats of such shallow tidal bays as Lake Tampalakamam.

The usual position is almost prone on the muddy surface, the hinge region slightly sunk in the mud, which lightly covers the dorsal third of the shell. Occasionally they are sunk more deeply, and they may even be found, though rarely, planted vertically after the manner of *Pinna*.

In the young condition, during the first year at least, the valves are perfectly transparent—the general anatomy of the animal can be clearly seen even to the beating of the heart. The very young up to the time they reach a diameter of two inches, not infrequently exhibit ray bands of palest pink diverging from the hinge and broadening as they approach the free edge of the shell. A few are almost entirely suffused with this pale pink tinge; others, and these are the majority, exhibit no colour, clear and transparent as the finest mica flakes, which indeed they resemble closely, even to the readiness with which they can be split into further lamellæ.

Towards the age of two years the shells as they become more massive gradually turn white and translucent in place of being clear and transparent.

From the observations I have been able to make, having visited the lake in 1902, 1903, and 1905, I conclude that three years constitute the life-span of this species; within this time they attain the size of 7 inches in length by 6 inches in depth (or height). This confirms Kelaart's statement:—"I am not able from my own observations (having been only a few months engaged in these researches) to say, in how many years this oyster arrives at perfection. But from the appearance of shells of all sizes, and the history of the Tamblegam pearl fisheries since 1839, I should say, that in three years this bivalve mollusc attains its adult age; and, after that, it dies." *

During my last visit I measured representatives of the different broods met with (see Annexure No. I.), and this record will enable the rate of growth to be ascertained with exactitude by means of further observations next year.

The shells of this mollusc are said to be used on account of their clear translucency as a substitute for window glass in China and in the Portuguese territory of Goa—whence arises the term "window oyster" as applied to this species, the "*Vitre chinoise*" of French writers.

In Ceylon such glazed windows would be a superfluity in native dwellings; the reason for the fishery of these oysters lies entirely in the abundance of small pearls yielded by full-grown individuals.

* "Report on the Tamblegam Pearl Oysters," 8vo., 6 pp., Trincomalee, 3rd October, 1857.

Of the past history of the fishery little is known, save that during last century a small and gradually diminishing revenue was drawn by Government from the rental of the fishing rights.

In 1857, Dr. E. H. Kelaart furnished a short preliminary report on the fishery (*loc. cit.*), wherein he states that during the two days he spent at Kinniei in 1857 there could not have been less than 30,000 oysters fished on each day. He adds: "More than two-thirds of this number were young and had better have been left in the lake for another year or more..... The Tamblegam Wanniah, and all the divers, whom I questioned on the subject, stated, that in the early part of the present year more than 50,000 oysters were fished daily..... At the lowest calculation, in three years there must have been fished from this bank upwards of 18 millions of oysters, supposing that there were only 200 fishing days in each year."

During the period of the three years in question the rental paid to Government by the lessee was £901, while for the eighteen years preceding 1857 the average annual rental was £344, rather higher than that of the final triad of years.

Between 1880 and 1890 the fishery, according to the Kachcheri records, was leased out three times, viz.:—

Year.	Lessee.	Amount of Rent. Rs.
1882–1884	Annamalai Chetty	3,000
1885–1887	do.	7,000
1888–1890	Arumugan	5,000

The fisheries during Arumugan's lease were carried on most thoroughly; in consequence, the long threatened complete exhaustion of the beds came about, and since 1890 no fishery has been held. The rent for 1897–1898 was indeed sold for Rs. 1,850, but the lessee dying, the lease was abandoned by his representatives, and on account of poor prospects it was not resold, no fishery taking place in consequence.

The beds have taken from 1890 to the present to make a partial recovery; they will require very careful treatment, largely protective, to ensure continuance and the distribution of further deposits over a larger area. The beds are still so restricted in extent that fishery greed if uncontrolled may easily bring about another long series of blank years, while on the contrary, if the fishery be carried on systematically and providently, it should become the source of a fairly regular annual revenue to Government of from Rs. 10,000 to Rs. 12,000, possibly even more.

Up to the present time the fishery in Tampalakamam Lake has invariably been leased by Government to native speculators—Chetties from Trincomalee and Jaffna—for periods of three consecutive years. The divers receive one-half the catch as their remuneration, but they are bound by custom to open their oysters fresh and to sell the pearls they find to the renter virtually for whatever he may like to give.

The renter also opens his oysters fresh, employing coolies to do this. I am informed that the pay is usually at the rate of some 12 cents per hundred.

The divers claim that each makes from 300 to 500 dives per day; they consider the yield satisfactory if they obtain an average of one large oyster per dive. When the oysters are abundant one man may fish from 2,000 to 3,000 per day.

The Kinniei divers distinguish between the true pearl oyster (*Margaritifera vulgaris*) and the window oyster by terming the former *Silavattai chippi*, the "pearl fishery oyster," and the latter *Muttu chippi*, the "pearl oyster."

The causation of the pearl in the window oyster and other details are dealt with on pages 48–49.

III.—Inspection of the Placuna Beds, May, 1905.

With a view to the systematic exploration of the lake, I laid off the area to be examined into four sections—(*a*) Nachchikuda, (*b*) the southern half of the central division, (*c*) the northern half of the same, and (*d*) the south-western division.

To each I devoted at least one day, running series of soundings and dives along the lines marked upon Sketch Plan No. 2 (Annexure IV.). Several hundreds of dives were made, and where the results of those adjacent to one another are identical with regard to the organisms found and the character of the bottom I combine them under the same number, as marked on the plan.

Those stations where *Placuna* was found are underlined.

IV.—Summary of Results.

Except at the inner end of the entrance to the lake and on the *kallams* or banks already alluded to, the general bottom of the lake is a fairly stiff grayish-black mud ; both fauna and flora are scarce, few organisms having adapted themselves to life under such environment. The two principal animals that have so succeeded are *Placuna placenta* and the peculiar Suberitid sponge which I found first in October, 1902, and which Professor Dendy is describing as a new species. The latter goes by the name of *Kadalpalam* (sea fruit) among the divers of Kinniei—an appropriate designation as it is roughly pear-shaped in form, with a ground colour of pale yellow, blotched on the larger end with red.

It lives rooted in the mud by silky tufts of spicules ; its abundance is associated in the minds of the divers with replenishment of the *Placuna* beds, which they aver is preceded by the appearance of this sponge. Probably this belief arises from imperfect observation, as when *Placuna* is not plentiful these men have no occasion to make acquaintance with the condition of the non-edible fauna of the bottom.

Algæ are scarce on what we may term the *Placuna* mud. Here and there a branched *Codium* clings to a perambulating gastropod shell inhabited by a hermit crab, or a stout fan-shaped species may occasionally be found rooted in sandy mud by bulbous base. Otherwise, save for crawling gastropods, there is little conspicuous life present.

Four distinct *Placuna* beds were found, one at the head of Nachchikuda, one off Kapalturai, a third fronting the coast between Kakamunai and the mouth of the Sembian-ar, with a fourth in the southern half of the south-west section of the lake.

That in Nachchikuda consists of very young individuals, none exceeding the size of a crown piece. The divers whom I had with me did not know of the existence of this bed, and were extremely pleased to find it, for, as they said, no sign of oysters had been seen here for very many years; the augury they inferred is of the best.

The bed off Kapalturai is also composed of young individuals, older by some three months than those of Nachchikuda. The average size is 3·33 inches by 2·92 inches, and over the greater part of the bed they lie in great profusion, from 10 to 22 being commonly brought up at one dive.

Another bed largely composed of similarly aged oysters was found to extend south-west of Kakamunai and to occupy the greater part of the bay off the mouths of the Tampalakamam-ar and the Periya Palamput-ar. Some older oysters of $4\frac{1}{2}$ inches by 4 inches were mixed with them, and in places there were considerable numbers of the very young, $1\frac{3}{4}$ to 2 inches in diameter.

The bed lying off the south shore, from Kakamunai eastwards to the mouth of the Sembian-ar, is by far of the greatest immediate value, for, while the age appears sufficiently advanced to admit of a fishery next year, their abundance is great enough to make such a fishery profitable so far as numbers are concerned.

Two ages are present, the one probably over 2 years old, and measuring $155\frac{1}{8}$ mm. by $142\frac{2}{8}$ mm. ($6\frac{1}{8}$ in. by $5\frac{5}{8}$ in.) and another considerably more numerous of from $1\frac{1}{2}$ to $1\frac{3}{4}$ year, measuring from $111\frac{5}{2}$ mm. by 102 mm. ($4\frac{3}{4}$ in. by 4 in.) to $125\frac{1}{5}$ mm. by 115 mm. (5 in. by $4\frac{1}{2}$ in.).

V.—Principal Details of Results.

A dug-out canoe pulled by four boatmen was employed for the first three days; work therefrom was most inconvenient in the high wind and choppy water which prevailed after 8 A.M.; during the latter part of my stay, by the courtesy of Mr. W. B. Gregson, the District Engineer of Trincomalee, I was enabled to use his roomy and more manageable cutter greatly to the improvement of the work performed both by the divers and by myself.

The divers of Kinniei are all Moormen, generally of poor physique and low intelligence. They do not care to dive in greater depths than three to four fathoms; none attend the pearl fishery in the Gulf of Mannar, neither do they take any part in chank fishing. Some of them in the season dive for beche-de-mer in Trincomalee Harbour; others employ themselves in net-fishing, and all do more or less work in the paddy fields of the district.

The first day's inspection was devoted to an exploration of Nachchikuda, a sleeve-like bay at the extreme eastern end of Tampalakamam Lake. A series of dives was made across the mouth and then continued up the western side. At the north end, where hillside jungle gives place to a fringe of mangrove swamps, a number of traverses were made, and here it was that the bed of 6 weeks old *Placuna* was located. Thence we returned homewards, keeping a course parallel with the eastern shore.

Stations 1 to 5 across the mouth of Nachchikuda :—

Station 1.—15 yards from the shore at Semmalai; 10 feet depth; bottom shelly sand with some gravel, fragments of dead *Ostrea*, also rock.

Station 2.—3 fathoms; fine brown muddy sand.

Station 3-3-3.—2 fathoms; dark coloured gritty mud with subfossil shells of a small species of *Turritella* abundant. A few fan-shaped stout algæ rooted in the sand, with some *Codium* on live gastropod shells.

Station 4.—Close to the shore at Vellai Kalumunai, 2 feet: gravel and pebbles mostly of white quartz, with small edible oysters in quantity; the latter are known locally as *kavatti* and corruptly as *quatti*; both forms are much in evidence in local nomenclature along the coast line of Tampalakamam and Trincomalee.

Large *Cerithium* shells inhabited by Pagurids are very abundant on the gravelly portions of the shore line.

Station 5.—About 40 yards there, from the along the western coast of the bay; ¾ fathom; bottom fine sandy mud, bearing an abundance of phanerogamic plants, chiefly *Halophila*

Station 5*a*.—At the head of the bay; 5 to 6 feet; black mud, with great abundance of very young *Placuna placenta*; *Halophila* present, but not abundant; nearer the shore the bottom becomes very soft and highly charged with organic matter.

Station 6.—A shallow *kallam* with less than 2 feet of water over it; gravelly muddy sand, largely calcareous. Small clams, *Venus* sp., extremely abundant. Every hut on the adjacent shore has a pile of dead shells of this species outside its door—a veritable kitchen midden.

Station 7.—1 to 1½ fathom; muddy sand.

The second and third days were occupied in the examination of the central division of the lake, during which two beds of *Placuna* were located, the one covered by the station numbers 8, 28, and 10: the other by stations 14 and 13.

These days' work brought out most clearly that the suitable bottom for *Placuna* is the soft, pasty black "ink mud," *mei seru*, that covers almost the whole of the bottom in this division in depths over half a fathom. Wherever an exceptional admixture of sand occurs, as for example towards the shore off the mouths of the Sembian-ar and the Polokarai-ar, no window oysters are present, though a hundred yards away on the *mei seru* they are brought up 12 to 16 at a dive! The particulars are :—

Station 8-8.—¾ to 1 fathom; black mud; abundance of oysters.

Station 9-9.—1 fathom; black sandy mud; no oysters.

Station 10-10, which is known to the divers as *Sembian-ar velangu*, was particularly prolific in fine, well-grown oysters from 10 to 16 to a dive lying on soft black mud; depth 8 feet.

Station 11 occupies the whole of the central portion of the division; depth 1 to 1¼ fathom; *Kadalpalam* (the peculiar new species of Suberitid sponge already mentioned) in quantity on soft black mud; no living oysters, but a large number of dead valves.

Station 12.—1 fathom, hard muddy bottom with sand admixed.

Stations 13 and 14.—1 fathom, muddy bottom; great quantities of oysters measuring 3⅓ by 3 inches, with a few of 6¾ by 6 inches, 7 to 22 per dive.

Station 15, in the mouth of Serukuda or Muddy Bay, a mangrove-lined inlet having an exceedingly soft muddy bottom, so soft that walking over the surface one sinks to the middle at every step. A second name is Settakuda (Dead Bay), as window oysters settling here invariably die before attaining even medium size. Depth ¼ to ½ fathom.

Near the mouth of Serukuda is Kumladdai maddam, now an uninteresting ruin of a small roadside resting place. The old road to Kandy passed this spot.

Stations 16 to 19.—1 to 1¼ fathom; muddy bottom.

Station 20.—Off the shore between Korrinjavat and Vellai Kalumunai. Depth 5 to 6 feet. Sand and mud; towards the south end some Kadalpalam. No oysters since leaving station 14.

The remaining part of the lake, the south-west division, took a further two days to survey. Combining the results we may summarize them as follows:—

Proceeding westwards from a point north of Kakamunai we passed south of the Amai-kallam; we found at station 21, 5 feet, the same conditions as at the adjacent station 8, black muddy sand without any oysters, but with some *Halophila*.

Station 22 and the three sections of station 23, all of 1 fathom, gave black mud with plenty of oysters at 22, 23*a* and 23*b*, 3 to 5 to a dive, varying in size from 6½ to 6 inches down to 3 by 2½ inches.

At station 24, 1 fathom, half a mile off the mouth of the Sinna Palamput-ar, bottom black sandy mud, no live oysters were met with, but large numbers of dead shells 1½ inch in diameter. The proximity of the river mouth will account for this mortality.

Station 25.—1 fathom; black sandy mud; no oysters.

Station 26.—On Muttikallam, a cockle-bearing sandbank nearly awash at low water.

Station 27.—Similar to station 11.

Station 28.—Similar to station 10.

Station 29.—On Amaikallam, a curious bank in half a fathom of water, lying midway between the mouth of the Sinna Palamput-ar and Kakamunai (see Sketch Plan No. 1, Annexure III.). Unlike Muttikallam, where the bottom is comparatively clean sand, that here is a dirty black sand charged with a considerable quantity of decaying vegetable matter and bearing a great abundance of *Halophila* and of algæ of various species. Turtles (*amai*) are said to resort here in January and February to browse on this vegetable life. No window oysters are ever found on this or any other *kallam*.

Station 30.—6 feet; black mud; a very few oysters 3½ by 3 inches at station 30*b*.

Stations 31 to 34.—½ to 1 fathom; black mud with varying quantities of young oysters, mostly of the 3½ by 3 inch size, seldom more than three or four to a dive.

Stations 35 to 38.—½ to ¾ fathom; no window oysters; bottom a black mud with some brown dichotomously branched algæ bearing a slender zoophyte in fair quantity.

VI.—Pearls and Pearl Causation in Placuna Placenta.

Value and uses of these pearls.—Allusion has already been made to the great abundance of pearls in full-grown individuals of *Placuna placenta*: Kelaart states (*loc. cit.*) that while the pearls they produce are about two-thirds less in value than those from the Gulf of Mannar pearl oyster (*Margaritifera vulgaris*), the quantity obtained in one thousand *Placuna* oysters is at least treble what is yielded by a

similar number of the other species. He adds that oysters of upwards of two years of age (*i.e.*, about 6 inches in diameter) were worth, in 1857, at least ten shillings a thousand, but if there be any competition among purchasers the price may rise to fifteen shillings a thousand.

So far I have seen but very few of these pearls; all were small, the larger being more or less irregular in form. I am told, however, that occasionally they are found sufficiently large and well shaped to be utilized in the manufacture of jewellery, nose ornaments and earrings principally.

The small size and imperfect shape of the vast majority entail quite other uses—uses that depend entirely upon Eastern customs, for who in Europe would at the present day think of using pearls as a constituent of a chewing mixture, as medicine, or as a passport or travelling provision for the dead? The only purpose for which they can have a sale in Europe is for the manufacture of a pearl facepowder or enamel, a demand for which has arisen within recent years! It has been the former uses, however, which have made the Tampalakamam pearl fishery a source of revenue to Government and a livelihood to some hundreds of divers in that district. Practically the whole supply of these pearls is exported to India, where the majority are calcined and made into a luxurious form of chunam, affected by the wealthy and ostentatious when partaking of their dearly loved betel.

A proportion are employed medicinally, chiefly in China, in powder or in solution, pearls having a recognized place in the ancient Eastern pharmacopœias. Another use is where a small quantity of these pearls is placed in the mouth of the dead before burial, in the same way that rice grains are occasionally similarly disposed, and with the same end in view as had the ancient Britons and early Saxons when they placed food and the requisites for a lengthy journey in the graves of their chieftains.

Of three of the oldest oysters met with in May, the average measure being 155 mm. by 142 mm. ($6\frac{1}{8}$ by $5\frac{5}{8}$ in.), one contained three minute pearls located in the free portion of the mantle. All were about midway between the pallial margin and the visceral mass, the same location where we find the finest class of pearls in the true pearl oyster.

The lustre of the smallest of those I have seen is good, but that of the larger ones is very inferior, while the indentation of the surface with a network of shallow furrows and grooves renders the pearls somewhat botryoidal in appearance. However, I have seen but four of a size larger than a pin's head, and I am told that all are not equally inferior. At the best, even if smooth skinned and of fair lustre, they cannot compete with *Margaritifera* pearls, as their substance is much less hard. A steel point scratches a pearl from *Margaritifera* with some difficulty—the resultant scratch is shallow and clean edged; a scratch made in similar manner on the surface of a *Placuna* pearl is easily effected, deeper and wider: where a mere line would be made in the one case, a gash results in the other. This is exactly what we should expect, arguing from the difference in the nature of the two shells, that of *Placuna* being micaceous or talcose in appearance according to age, and having hardness approximating rather to that of these minerals than to that of ordinary calcite.

No investigation whatever has hitherto been made into the causation of pearls in *Placuna placenta;* no suggestion even has been hazarded so far as I know. Therefore, considering how divergent the environment in which *Placuna* lives from that of the true pearl oyster, I was not prepared to find the cause to be identical. This, however, proves to be the case; out of five minute pearls which I have found in the tissues of *Placuna* I have so far sacrificed two, dissolving the investing coats of carbonate of lime with weak hydrochloric acid. In each case the nucleus proved to be the dead remains of a minute Platyhelminthian larva of the same stage and species as that which forms the nucleus of cyst pearls in *Margaritifera vulgaris*.*

The next step was to ascertain under what conditions this parasitic worm exists in the tissues. For some time my search was fruitless; none of the opaque white cysts of this larva so conspicuous in the liver and upon the gills of *Margaritifera vulgaris* were to be seen, but finally I located a number of the

* Shipley and Hornell, "The Parasites of the Pearl Oyster" in Professor Herdman's "Report on the Pearl Oyster Fisheries of the Gulf of Manaar," part II., 1904.

cysts within the dorsal portion of the visceral mass just above the stomach. Searching in the same locality in other individuals, similar groups of cysts were noticed in every case.

In details of form and structure these larvæ appear identical with the spherical larvæ found in *Margaritifera vulgaris;* in size and grouping they show marked divergence. In *Margaritifera* I have never found them in definite groups of numerous individuals as here (see Annexure II., fig 2); in the former case, although I have occasionally come across small clusters of two and three, the rule is for the cysts to be scattered singly through the tissues most affected. In *Margaritifera vulgaris* many of the cysts are a full millimetre in diameter, while some even exceed this size—conspicuous to the naked eye; in *Placuna* the larvæ are all very minute, averaging from 0·2 to 0·4 mm. in diameter, and aggregated into populous groups of as many as 50 individual cysts.

These cyst groups are tightly packed, the membranes of many cysts actually in contact. Moreover, there is a great range in size, some being but one-quarter the diameter of others.

With such an abundance of material I passed some hundreds in review under the microscope, hoping to settle some of the minor points of detail yet in doubt. In all particulars they tallied with the form already studied, the only point of additional structure made out being that in the larger forms the terminal excretory pore was seen to be lined with bristle-like cilia (Annexure II., fig. 3) in a similar manner to that described for the excretory funnel in the advanced larvæ of *Tetrarhynchus unionifactor*.*

A much more important observation, and one throwing light on the still obscure and puzzling life-story of this economically valuable parasite, was my finding parthenogenesis to be taking place within the bag-like bodies of these encysted larvæ. In three different instances a miniature reproduction of the parent was seen within the bladder-like posterior division of the body. So far as my observations go only one secondary larva is produced at a time; the structure of the latter appears identical with that of the mother. Calcareous corpuscles were already present within the asexually produced stage, though of proportionately smaller size (Annexure II., fig. 1).

It appears to me probable that the young individuals which arise in the manner described eventually make their way through the body wall of their parents and form separate cysts; in this way the numbers in the cluster or group gradually increases and will account for the large numbers present without the necessity to invoke individual infection repeated scores of times.

The parthenogenetic reproduction of this particular pearl-inducing parasite enables us to understand the hitherto puzzling fact that true cyst-pearls in *Margaritifera vulgaris* are quite frequently found in small clusters of two, three, and even four or more, for while this mode of increase in numbers has not yet been signalized in that oyster, such I have now no doubt does there occur also, and furnishes a satisfactory explanation of the occurrence of clustered cyst-pearls.

The only other entozoon found in *Placuna* proved to be the handsome Nematode *Cheiracanthus uncinatus*, which is also common in the true pearl oyster. As in the latter, it finds its lodging encysted within the adductor muscle and is in the larval stage.

VII.—Conclusions and Recommendations.

The outstanding conclusions with regard to the causes which have involved a suspension of the Tampalakamam pearl fishery for many years, with gradual deterioration for a long preceding period, are more readily arrived at than is the formulation of a scheme for the efficient protection of the beds and the profitable conduct of future fisheries. The causes of dearth in the one case and the difficulty of regulation in the other, both spring from the peculiar situation of the beds—from the fact that they lie in a comparatively restricted area of shallow water whereby overfishing and related malpractices are facilitated. But if the regulation of this fishery be difficult it is far from being impossible, and I shall now try to show how the desired end may be attained.

* Hornell, "Report on the Operations on the Pearl Banks during the Fishery of 1905," in Ceylon Sessional Papers (XXXIII.) for 1905.

Unrestricted fishing in the past, coupled with a total disregard of the most elementary biological axioms, have been the sole causes of the suspension of the fishery. Only the wonderfully prolific reproductive powers of the oyster delayed the temporary extinction of the beds, for so long ago as 1857 we find Kelaart writing :—" The banks have become overfished. The Natcha Cooda bank is completely destroyed. The renter in 1856 left scarcely any oysters behind, and this portion of the bank will consequently be unproductive for many years."

Further on he states that he observed the renter, free from any remonstrance on the part of the Government Agent, to be " bringing up daily 5,000 to 6,000 oysters scarcely more than eight months old, and which cannot yield more than sixpence worth of pearl in each thousand, if they do that."

The chief faults of the control here, as also with regard to the Gulf of Mannar pearl banks, have been the total disregard shown in past years by the authorities to the absolute necessity to preserve adequate breeding reserves and to afford, in the case of Tampalakamam, protection to the immature oysters. In respect of the latter safeguard, Kelaart put the matter bluntly but truly: " The Government Agents who could have acted so unwisely as to lease out to native renters a small bank of pearl oysters for three consecutive years, without any stipulation as to the size of the oysters to be fished, must have lost sight of the natural laws of reproduction and multiplication of species, known even to the native divers."

The whole of the evil has arisen from this obnoxious system of leasing the banks without control as to the number of oysters to be removed or the size at which they should not be fished. The remedy lies in the recasting of the methods of management and the enactment of rules for the regulation of fishing.

The remedial measures which I recommend for adoption are :—

I.—The enactment of an Ordinance vesting the rights to this fishery wholly in Government, that is to say placing the Government monopoly of this fishery on a legal basis, whereby the authorities may make such bye-laws for the conservation of the beds and the regulation of fishing as they may deem fitting. Hitherto the right of Government to lease out the fishery has been based solely on prescriptive usage: there appears to be no enactment conferring exclusive rights upon the Government. In consequence it might be difficult for the authorities to sustain at law any prosecution for infringement of regulations relating to illegal removal of oysters. Without such enactment the appointment of watchers can have little or no value.

I may mention here that any enactment made with regard to the protection of the *Placuna* pearl beds will not affect the local fishermen's prescriptive right to fish edible oysters, as none are found in the vicinity of the pearl beds. The latter are all in the central and south-western divisions of the lake; the edible oysters solely on the rocks at the entrance.

II.—Fishery on Government account should be substituted for the system that has hitherto prevailed of renting out the fishery for periods of three years. Probably the best plan would be for the Government to have an enclosure or kottu put up in the vicinity of the bed to be fished, whereto all oysters must be taken each day. In view of the comparative smallness of the fishery it would be unnecessary to sell the oysters daily. It would probably be adequate if the Government Agent attended (say) once a month and then put up to auction the oysters to be fished during the ensuing month, the price to be not a lump sum, but a rate per one thousand, as customary at the Marichchukaddi auction. This method of sale, I believe, would have the two-fold effect (*a*) of stimulating competition and thereby ensuring better prices, as by the smaller rental involved a larger number of capitalists would be enabled to enter the field; and (*b*) of making the transaction one of legitimate business, and not a mere speculation or gamble, as it has been hitherto. In the past the sale of the fishery for periods of three years led to the preferment of many claims against Government by the lessees for alleged losses sustained. Some of these claims no doubt were *bona fide*, but many were, I believe, misrepresentations, and as the Government had

no satisfactory means to check the statements made, remissions of part rental were not infrequent, with consequent loss to the Government.

Another fraudulent device alleged against past renters is the one of obtaining cancellation of the lease with subsequent resale, a relative of the original renter stepping in to purchase at a greatly reduced figure!

III.—A clause in the terms of sale should require that the renter shall buy the whole of the divers' share of the daily catch at the same rate per thousand as he may be paying to Government.

Hitherto an unfair practice has prevailed compelling the divers to open their share of the oysters while fresh and to sell to the renter all the pearls found at a fixed rate, which the renter takes good care is well below the market value. It is not advisable that there should be much huckstering of oysters or of pearls in the village, but it is, I think, the duty of Government to see to the removal of a very real grievance and so help to ensure to the toiler a proper return for his labour and protection against the wiles of the Chetty.

IV.—If the disposal of the divers' share be placed on a more equitable basis, the proportionate amount of their share should be reduced if possible from one-half of the total catch, at which it has stood hitherto, to one-third, thereby bringing the remuneration given into line with that prevailing at the Marichchukaddi fishery.

There is no comparison between the ease of fishing oysters in the two places—the water over the beds in Tampalakamam seldom exceeds six feet—and there is no reason for so large a proportion of the catch falling to the divers' share other than the unfair custom that has prevailed of giving less than market price for the produce of the share. Were the divers to be paid a fair price for a one-third share, they would be very much better recompensed than under the rule of receiving a half, to be disposed of at a rate fixed by the renter.

V.—It has been the renter's custom to prosecute the fishery off and on for the greater part of the year. I recommend that fishing be limited to the period between January 15 and May 15. Fishing during the rest of the year must be at best more or less desultory on account of the weather; it will be more profitable to prosecute the fishery vigorously during the period of favourable weather and to close it entirely for the rest of the year. When the men are in a position to earn a good wage by straightforward work, there is not the same inducement present to indulge in underhand practices that there is when the weather makes the catches small and the work arduous.

If direct Government supervision be given to the fishery, this will be a further reason to curtail the duration of the fishery, seeing that such supervision spells expenditure.

VI.—A minimum size at which the oysters may be fished must be specified; penalties for contravention should be severe, and every effort made to enforce respect for such a bye-law. The size which I suggest is $5\frac{1}{2}$ inches in shortest diameter.

Such are the principal modifications in the manner of conducting this fishery which I propose for consideration. Later, at a future date, when our knowledge of the life-conditions of the window oyster become more exact, further means may be taken to make the harvest of the beds more abundant—simple cultural methods may be introduced, such for example as the transplantation of young from unfavourable positions, together with the stocking of other of the muddy tidal lakes so numerous on the Ceylon coast line. I see no reason why profitable *Placuna* beds should not be formed in Batticaloa and Puttalam lakes to the advancement of the local prosperity and the good of the general revenue. But working experience and investigation on the spot must precede such stocking, and for such I have had as yet no opportunities.

At the present time there is no bed of oysters in Tampalakamam Lake ready for fishing. The most advanced bed, that off Kakamunai and the Sembian-ar, will not be ready at earliest till February of next year. The pearl yield is just now insufficient to tempt poaching on any extensive scale, and for this reason I recommend that the present watchers be discharged.

Early in January next the Assistant Government Agent at Trincomalee should be requested to draw a large sample, say of not less than 1,000 oysters, and to have the pearl yield therefrom valued by a local merchant. The result will decide the advisability or not of holding a fishery during the ensuing three months.

Should the weight or the value of the pearls appear sufficiently satisfactory to justify a fishery, then it might be useful to re-employ a couple of reliable men as watchers, but unless really trustworthy men be obtainable it would be preferable to have none. Personally I do not think that poaching is likely to take place on a large extent so long as the Wanniah does his duty; were it prosecuted on an extensive scale the matter would become notorious and easily traceable, while so long as it is restricted little or no harm is done. My experience of watchers or "guards" at the Marichchukaddi fishery prejudices me against the class, and inclines me to think their presence is dear at the wages they receive.

The best way to obviate poaching lies, in my humble opinion, in the exercise of such foresight and care in the management of the beds as will ensure a lucrative annual fishery and by showing the men of the district that the Government is exploiting the beds not merely as a revenue milch cow, but as a local industry deserving of fostering care.

VIII.—Synopsis of Recommendations.

(1.) The discharge of the present watchmen appointed to look after the pearl beds.

(2.) The enactment of an Ordinance vesting the monopoly of the fishery for window oysters (*Placuna placenta*) in Government and giving the authorities power to make by-laws for the protection of the beds and the proper conduct of the fishery.

(3.) The abolishment of the old system of renting out the fishery for periods of three years; the substitution of a fishery on Government account, with periodical auction sales of the oysters at a rate per thousand.

(4.) The divers' share of the daily catch to be reduced to one-third; but

(5.) Protection to be given the divers to ensure that they receive as good a price for their oysters as does the Government.

(6.) Limitation of the fishing season to the period between January 15 and May 15.

(7.) No oysters to be fished of dimensions under 5½ inches in shortest diameter.

(8.) Further study of the life-history of the window oyster with a view to the stocking of other tidal lakes therewith and the creation therein of pearl beds similar to those at Tampalakamam.

In conclusion, I have to record my great indebtedness to Mr. W. L. Kindersley, Assistant Government Agent at Trincomalee, and to Mr W. B. Gregson, District Engineer, for much kindly help and advice, without which I should have been unable to complete the investigation satisfactorily in the limited time at my disposal. Mr. Kindersley, I believe, views my various proposals favourably, and if there be a fishery at Tampalakamam under his direction, the great personal interest which he takes in the establishment of the industry on a stable and enduring basis should go far towards ensuring success.

Mr. Gregson took an equally keen interest in the prospective development of the fishery. He suggested the utilization of the great mounds of shells littering the margin of the lake, relics of former fisheries, for the purpose of lime manufacture, and had I been able to stay at Tampalakamam a few days longer we should have made a trial burning. At present the Public Works Department requires considerable quantities of lime for use in this district, and in the absence of a local supply considerable transport charges have to be incurred. I see no reason why these shells, composed of calcium carbonate as is the case with all mollusca, should not make excellent lime; Mr. Gregson was making arrangements to have a quantity calcined experimentally at the time I left Trincomalee.

LIST OF ANNEXURES.

No. I.—Dimensions of three series of *Placuna placenta* from Lake Tampalakamam, 19th May, 1905.

Plate I.—The pearl-inducing worm larva of *Placuna placenta* :—

Fig. 1.—A larva from the liver of *Placuna* extracted from the cyst membranes and showing within the posterior part of the body a young individual (*p.l.*) of a second generation produced parthenogenetically.

Fig. 2.—A group of cysts containing larvæ of similar species to that shown in fig. 1 ; *p.l.*, parthenogenetic larva within the body of the mother.

Fig. 3.—A larva of the same stage as fig. 1 ; an excretory funnel is present at the posterior extremity, lined by stiff bristle-like cilia (*cil. ex. f.*)

Plate II.—Sketch Plan (No. 1) of Lake Tampalakamam showing the disposition of the beds of *Placuna placenta* in May, 1905.

Plate III.—Sketch Plan (No. 2) of Lake Tampalakamam showing the route followed in the inspection of the pearl beds and the position of the various stations.

JAMES HORNELL,
Marine Biologist to the Ceylon Government
and Inspector of Pearl Banks.

Colombo, June 15, 1905.

ANNEXURE I.

Dimensions of three series of Placuna Shells (Living) taken from Kakamunai Bed, Tampalakamam Lake, 19th May, 1905.

Series I.

No.	Length. mm.	Depth. mm.
1	158	138
2	155	147
3	150	122
4	159	143
5	134	146
6	160	145
7	165	150
8	160	147
	1,241	1,138

Average, $155\frac{1}{8}$ mm. by $142\frac{1}{4}$ mm.
Approximately, $6\frac{1}{8}$ by $5\frac{5}{8}$ inches.

Series III.

9	110	104
10	116	115
11	105	92
12	116	109
13	112	92
14	110	104
15	111	100
16	110	107
17	117	102
18	100	95
19	109	99
20	121	105
	1,337	1,224

Average, $111\frac{37}{100}$ mm. by 102 mm.
Approximately, $4\frac{3}{4}$ by 4 inches.

Series II.

No	Length. mm.	Depth mm.
1	119	110
2	110	110
3	120	110
4	124	119
5	129	113
6	126	109
7	127	111
8	125	123
9	133	124
10	131	123
11	119	108
12	115	115
13	125	114
14	125	114
15	119	114
16	122	117
17	118	101
18	125	108
19	127	113
20	116	105
21	124	104
22	122	106
23	120	120
24	139	120
25	120	110
26	129	118
27	143	129
28	125	122
29	144	120
30	130	124
31	130	124
	3,881	3,564

Average, $125\frac{5}{31}$ mm. by $114\frac{30}{31}$ mm.
Approximately, 5 inches by $4\frac{1}{2}$ inches.

Fig. 1.

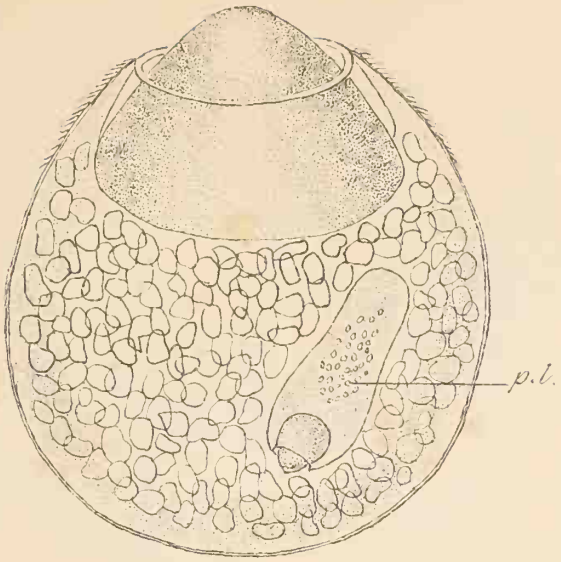


Fig. 2.

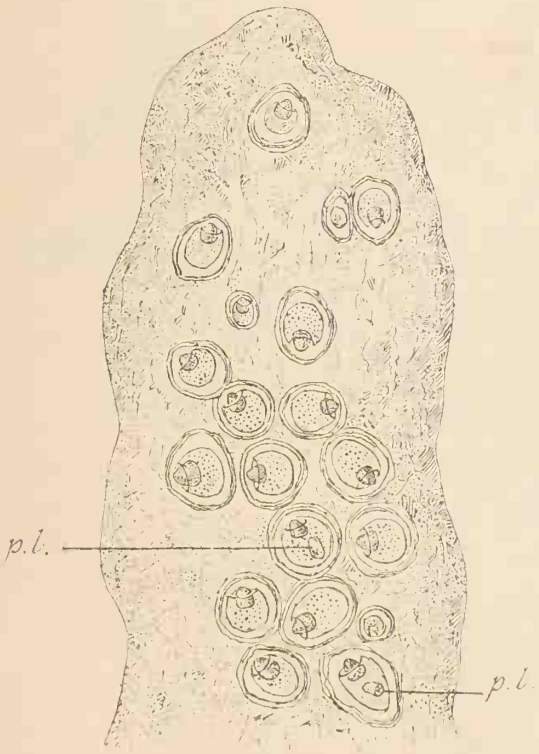
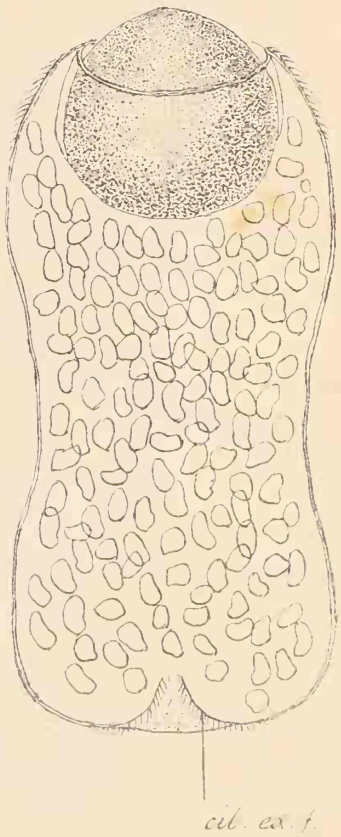


Fig. 3.

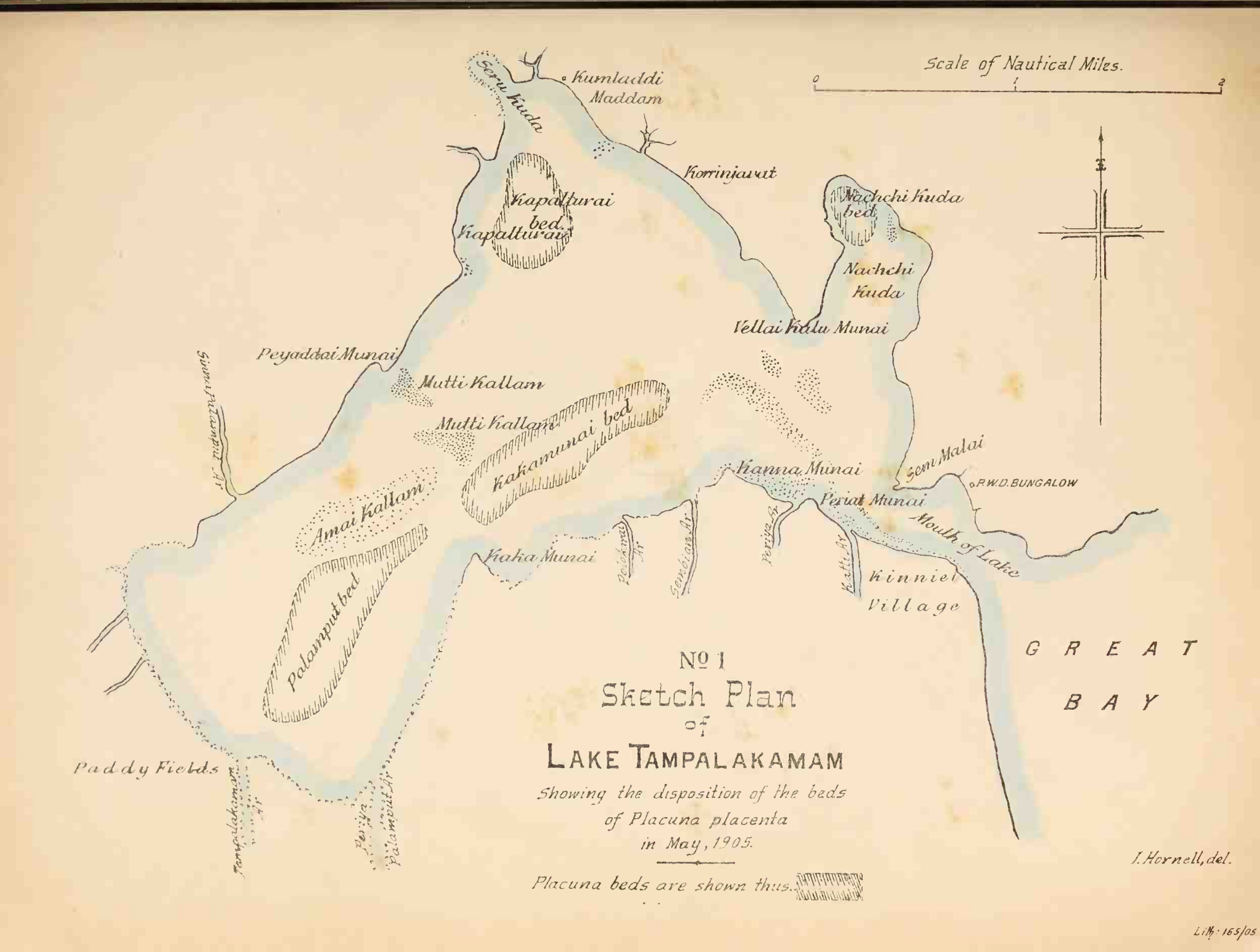


THE PEARL-INDUCING WORM LARVÆ OF PLACUNA PLACENTA

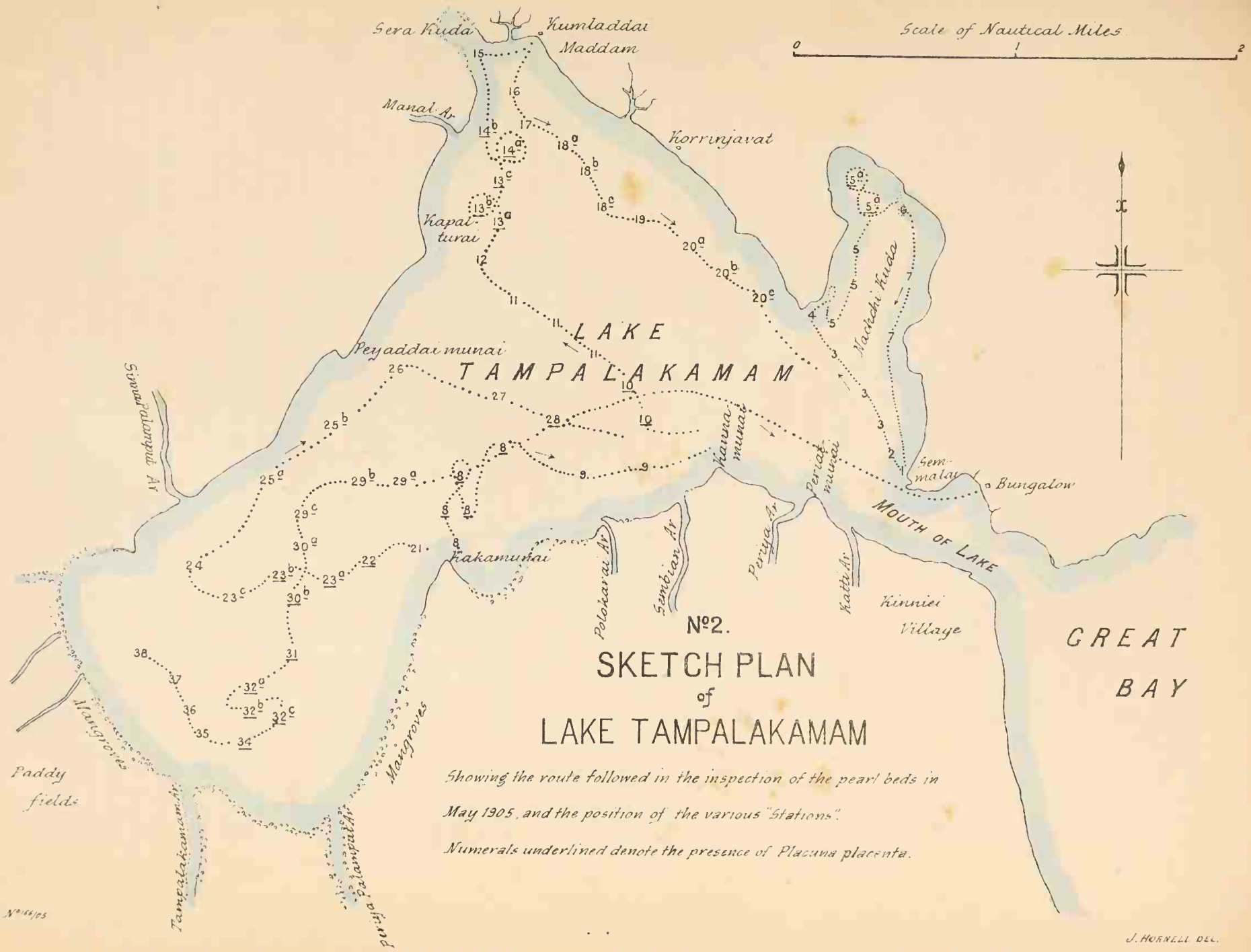
~~*Distomum Margaritiferum N. Sp.*~~
~~*from Placuna Placenta*~~

J. Hornell. del.

G.G. No. 164/05.


Scale of Nautical Miles.
0
1
2
Seru kuda
Kumladdi Maddam
Korrinjaiyat
Kapalturai bed.
Kapalturai
Nachchi kuda bed.
Nachchi kuda
Vellai kalu Munai
Peyaddai Munai
Mutti kallam
Mutti kallam
Kakamunai bed
Amai kallam
Palamput bed
Kanna Munai
Periat Munai
Sem Malai
P.W.D. BUNGALOW
Mouth of Lake
Kinniel Village
Kaka Munai
Paddy Fields
GREAT BAY
No 1
Sketch Plan
of
LAKE TAMPALAKAMAM
Showing the disposition of the beds of Placuna placenta in May, 1905.
Placuna beds are shown thus.
I. Hornell, del.
Lith. 165/05

ANNEXURE. IV.



№2.

SKETCH PLAN
of
LAKE TAMPALAKAMAM

Showing the route followed in the inspection of the pearl beds in May 1905, and the position of the various "Stations".

Numerals underlined denote the presence of Placuna placenta.

Lith. S.G.O. №164/05

J. HORNELL DEL.

No. 3.

REPORT ON THE OPERATIONS ON THE PEARL BANKS DURING THE FISHERY OF 1905.

With one sketch-plan.

By JAMES HORNELL, F.L.S.

I.—THE FINAL INSPECTION PRIOR TO THE FISHERY.

(*a*) Distribution, Age, and Number of the Oysters found.

Consequent upon the report made in December of last year upon the facts ascertained in the course of the November inspection concerning the state of the maturing oysters on the pearl banks, Government decided upon the proclamation for fishing in 1905 of the beds lying on those sections of the pearl banks respectively known as the South-West Cheval, Mid-East and South-Central Cheval, South Cheval, and North and South Moderagams. It was further decided that the commencement of the fishery should be accelerated as far as possible, in view of the large number of oysters to be fished and the uncertainty pertaining to weather conditions at the fishing season. 20th February, therefore, was decided upon as the day when the fishery should begin, this being considered the earliest date on which we could count upon the attendance of divers and merchants.

This proposed acceleration of the opening of the fishery reduced the time available for the final inspection, while as weather conditions precluded the date of the commencement of the latter earlier than the last week in January, it was not till 26th January that I was able to leave Colombo on this duty aboard the barque "Rengasami Poravi." The steamer "Violet," fitted up as an oyster dredger, left in company, having received a thorough overhaul and additional equipment in the interval since her return from the pearl banks at the end of last year.

Headway was slow owing to strong contrary winds from the north and north by east; it was the afternoon of 28th January ere we reached our destination. The next day was spent in landing stores, making arrangements for the subsequent watering of the vessels, and other matters incidental to the inception of an inspection. All else was in order and ready for an immediate start; the "Serendib," which was allotted to me as attendant launch for the purposes of towage and the laying out and lifting of the inspection buoys, had arrived, and the staff of divers were already aboard the barque, having travelled to Colombo by British India steamer from Paumben, instead of *vid* Mannar as heretofore, the recommendation to this effect made in my November report having been sanctioned.

The actual work of inspection began on 30th January and continued for ten days. Within this time a careful examination was made of the banks to be fished, the approximate numbers of oysters estimated as accurately as the means available permitted, the contour of the oyster-bearing area laid down upon the chart, boundary buoys placed in position, and valuation samples of oysters collected from the beds to be fished. I was anxious to examine the ground outside the bank limits, but the time at my disposal was too short to allow this to be done.

The results as regards the distribution, numbers, and condition of the oysters were as follows:—

South Cheval Paar.

The general condition of the oysters remained the same as when examined in November, 1904. The individuals were in the main remarkable for vigorous growth, clean, healthy appearance, and freedom from disease. The bed was large and compact; oysters were distributed over the whole of the section, except for two deep barren indentations on the west side. To the north the bed merged with the oysters on the South-Central and Mid-East blocks; on the north-east a narrow neck connected with the irregular bed of the South-East section, while to the south of this point the bed extended some distance eastwards beyond the arbitrary boundary between the South and the South-East sections.

The great majority of the oysters were from 3 to 3½ years of age with irregularly scattered patches, varying considerably in extent and density, of an older generation, whose age I estimated to be from 5¼ to 5¾ years. These also were lusty in growth, and obviously held excellent pearl-producing potentiality. The irregularity of their distribution rendered the gathering of a fair representative valuation sample a matter of considerable difficulty, and, as will be seen later, entailed eventually much additional trouble.

An extremely careful calculation of the extent of the oyster-bearing area of the South Cheval bank, together with the bordering bed lying on the west side of the South-East Cheval, gave the total as 6,700,000 square yards. In the southern region, over an area of 3,900,000 square yards, the oyster population was the more crowded, giving an average slightly over twenty-six per dive. Over the northern third of the bank, where the oyster-bearing area was approximately 2,800,000 square yards, the average per dive dropped to fourteen. The combined areas gave a total of fishable oysters of 47,500,000, made up of 40,500,000 on the South Cheval and 7,000,000 on the portion of the South-East Cheval which marched with it.

The small bed of brood oysters noticed in November at the centre of this bed is now practically non-existent. In November forty-six dives recorded brood oysters. In the same section in February young oysters were recorded on four occasions only. This signifies the virtual disappearance of the patch.

Mid-East and South-Central Cheval.

Mature oysters were found occupying the same areas on these two sections as was indicated in the report of last November. On the north and north-west portions of the conjoined bed considerable apparent decrease in the number of the older oysters had taken place, principally owing to the rapid growth of the associated brood oysters, which were still exceedingly abundant; wherever these brood oysters occurred, the older oysters, principally 3½-year olds, were poor in condition and lacking that vigorous growth characteristic of their fellows on the South Cheval. A natural decrease in the oyster population was undoubtedly in progress, and the utmost estimate I could frame of their numbers was 9,000,000 spread irregularly over an area of 1,900,000 square yards with oysters ranging from five to twenty-five per dive.

A considerable number of the oysters of this region showed brown spots and blotches on the nacre, due to inflammatory conditions in the mantle, thereby denoting a critical state of health and indicating the need for the early fishing of this bank.

South-West Cheval.

The small remnant of 3,000,000 of 6-year old oysters discovered on the South-West Cheval last November was next sought for. Two days were spent in thoroughly exploring the ground, with disappointing result. Of the 3,000,000 present in November, less than a million (900,000) remained in February. These were scattered sparsely over 140,000 square yards, and varied

from two to ten per dive. Such poverty of numbers, coupled with very irregular distribution, made their fishing impracticable, and prevented even the lifting of a valuation sample. Old age was at work, and seven years may be taken as the utmost span of the Ceylon Pearl Oyster's existence, *pace* John Christopher Wolf, who states* that fourteen years are necessary to the ripening of pearl oysters and the production of "perfect pearls."

Time did not permit of a further examination of the isolated bed on the South-East Cheval, this being immaterial, as the fishery thereon is postponed till next year. I estimate, however, that the number of mature oysters present in February, 1905, was 13,000,000.

North and South Moderagam Paars.

The condition and numbers of the South Moderagam oysters were practically unchanged. The main bed, which alone I had time to examine, had an oyster-bearing area of 2,750,000 square yards: the average of oysters was seventeen per dive, and as I reckon a dive to clear $2\frac{1}{2}$ square yards on this particular ground, the total number here was 19,700,000, a decrease of 1,300,000 since November. On the south-east side, however, the bed extended beyond the limit of the ground inspected, and there was therefore a probability that the actual numbers would prove considerably in excess of the estimate.

Brood oysters were again exceedingly abundant, crowding on the valves of the old and rendering the continued existence of the latter most precarious. As with the similarly circumstanced oysters of the Mid-East Cheval, the older generation showed the evil effects of this overcrowding in arrest of growth, stunting of the internal organs, and a general tendency to the development of inflammatory centres in the tissues of the mantle. The two cushion-stars, the variable *Pentaceros nodosus* and the lovely crimson-lake coloured *Pentaceros linckі*, were present in extreme profusion, due, I believe, to the sickly condition of the oysters rendering them an easy prey to these greedy devourers. The spat on this bank I consider sufficiently abundant to have ample margin for all the wastage likely to occur and as promising to yield a fishery in 1908.

The *North Moderagam* received greater attention than it did in November; a considerable extension to the north was traced; in consequence the oyster-bearing area was increased to 1,500,000 square yards bearing 10,000,000 oysters, ranging from ten to forty per dive, with a general average of eighteen per dive. The health of these oysters was very indifferent; various burrowing enemies, especially sponges and worms, were numerous, and some four per cent. were affected by the "yellow" disease. Everything pointed to the advisability of fishing these oysters as early as possible, but unfortunately they were also the poorest in size, appearance, and pearl yield, and likely to fetch but poor prices at auction.

SUMMARY OF THE RESULTS OF THE INSPECTION.

Paar.	Oyster-bearing Area in Square Yards.	Number of Oysters per Dive.	Estimated Number of Oysters.
South Cheval	6,700,000	From 14 to 26	40,500,000
South-East Cheval (portion bordering east side of South Cheval) ...			7,000,000
Mid-East and South-Central Cheval...	1,900,000	5 to 25	9,000,000
South-West Cheval	140,000	6	900,000
North Moderagam	1,500,000	18	10,000,000
South Moderagam	2,750,000	17	19,700,000
For fishery in 1906:—			87,100,000
Add for unexamined portion of South-East Cheval, approximate estimate			13,000,000
Grand Total of Fishable Oysters ...			100,100,000

* "The Life and Adventures of John Christopher Wolf, late Principal Secretary of State at Jaffnapatam in Ceylon." English Translation, London, 1785. He naively remarks: "A connoisseur in these matters can tell the age of an oyster as exactly by looking at it, as the dealers in cattle can that of an ox by looking at his horns. But during these fourteen years there is always some fresh oyster seed deposited under (*sic*) the old, and consequently in every fishery they get pearls of all sorts some large and perfect, some middling, and some small."

For the same series of banks the aggregate of the estimate of November, 1904, was 106,770,000, an approximation in results that was most satisfactory as a guarantee of the general accuracy of the method of numerical estimation employed. The number available for fishing in 1905 as above shown, after deduction of the 900,000 on the South-West Cheval, was 86,200,000. (The number actually fished was 81,876,520!)

(*b*) Valuation Results.

On 10th February the inspection being completed I returned to Marichchukkaddi, landed the last collected sample of oysters, and set about the washing of those first gathered. By the 15th the work was ended, and the various samples of pearls ready for the valuers. The results are tabulated as follows :—

Number of Oysters.	Paar.	Weight of Pearls obtained.		Weight of Pearls per 1,000 Oysters.		Total Value in Rupees.	Value per 1,000 Oysters.
		Kalanchu.	Manchadi.	Kalanchu.	Manchadi.		
						Rs.	Rs. c.
10,000	South Cheval	3	$5\frac{1}{16}$	—	6·5	127	12 70
2,400	Mid-East Cheval	—	$13\frac{4}{16}$	—	5·52	49	20 $41\frac{2}{3}$
5,000	North Moderagam	—	$16\frac{5}{16}$	—	3·3	40	8 0
6,000	South Moderagam	2	$1\frac{12}{16}$	—	6·96	99	16 50

Comparison with the valuation of the samples gathered three months previously shows that while the Mid-East Cheval oysters had made a most satisfactory pearl increase from Rs. 13·21 to Rs. 20·41$\frac{2}{3}$ per 1,000 oysters, and while those of the South Moderagam remained virtually unchanged in value, the valuation of the South Cheval was most disappointing. The irregular distribution of patches of rich 6-year old oysters over this ground has already been indicated, and it was very evident from the result of the valuation that the boats had been unfortunate in the ground they ranged over when collecting the second sample. As it was felt that the latter did not furnish a fair indication of the true value of the oysters on this section, a third sample was gathered from the central region of the South Cheval under my personal supervision. This proved thoroughly satisfactory in results, giving a valuation of Rs. 31·10 per 1,000 oysters. Probably the average of the three valuation results (Rs. 24·65, Rs. 12·70, and Rs. 31·10), Rs. 22·82 per 1,000, is the most accurate index of the true relative value of the oysters over the entire bed, a conclusion borne out by comparison of the relative average prices given during the fishery for oysters from the different beds.

Examination of the prices which ruled for oysters throughout the fishery gives the impression that these sample pearls were very greatly under-valued. It has to be remembered, however, that these latter valuations were given prior to the opening of the fishery, and that the market value of pearls became greatly enhanced within a few days after the beginning of fishing operations. I have evidence that pearl values became at least trebled within the period mentioned.

This enormous enhancement of values during the course of the fishery enables us to understand why merchants eagerly vied with each other to pay from Rs. 60 to Rs. 124 per 1,000 for oysters which had been valued prior to the fishery at from Rs. 20·41 to Rs. 24·65 per 1,000. The high prices paid were quite consistent with the reaping of fair profits, provided the oyster merchants sold while the pearl market remained inflated. I am strongly of opinion that the original holders of pearls were on the whole considerable gainers during the fishery ; the eventual losers are likely to be the "bulls," those who have bought pearls at high prices and are now holding. The situation so far as they are concerned is an ordinary gambling speculation, and has ceased to be legitimate trade.

(*c*) Recoupment of Expenses from Sale of Valuation Pearl Samples.

In the course of the November, 1904, inspection, 87,500 oysters were collected by the Government staff of divers. Of this quantity, 66,750 were washed by the men under my supervision, and during the recent fishery the pearls therefrom were sold at auction by Mr. Lewis. They realized the sum of Rs. 3,120, made up as follows :—

Quantity.	Locality.	Valuation. Rs. c.	Proceeds of Sale. Rs.
15,000	Mid-East Cheval	198 20	580
5,250	South-East Cheval	56 50	136
1,500	North-West Cheval	—	72
15,000	South-Moderagam	268 0	731
20,000	South Cheval	335 86	1,500
10,000	Muttuvaratu	31 67	101
		890 23	3,120

To this amount must be added the value of the remainder, 20,750, handed to Mr. Dixon to be put through his washing machinery. I do not know what they realized, but if valued *pro ratâ* with the hand washed, we should add for—

750	from South-East Cheval		19
20,000	from South Cheval		1,500
87,500		Total	4,639

This sum of Rs. 4,639, although it goes to swell the gross proceeds of the present fishery, was earned by the inspection staff, and constitutes a revenue that more than recoups the expenditure upon the inspection of November, which, including all salaries, wages, and stores, did not exceed Rs. 3,500 in all. Properly and economically conducted, the inspection of the pearl banks may frequently be made self-supporting, as in the instance now indicated.

II.—THE PEARL FISHERY OF 1905.

Summary of Results.

As already indicated, the beds fished this year were the—

South Cheval and bordering part of South-East Cheval, estimated to bear	47,500,000 oysters
Mid-East and South-Central Cheval, estimated to bear	9,000,000 ,,
North Moderagam, estimated to bear	10,000,000 ,,
South Moderagam and ground south thereof, over	19,700,000 ,,
A total of over	86,200,000 oysters

The aggregate number of pearl oysters actually fished by the divers and the dredger "Violet" approximated very closely to the estimate, being 81,876,520, by far the greatest number fished in any one year of which we have record. It all but equals the combined totals of the two great fisheries of 1903 and 1904, and is not far from double the highest number taken in any other fishery concerning which we have authentic information, namely, 44,311,441 in 1891. The following is a tabulation of the particulars of the daily takes by the divers.

Table showing the Place of Origin of the Oysters fished, February 20 to April 25, 1905.

Date.	No. of Boats engaged.	Total Number of Oysters lifted by Divers.	From what Beds obtained.					
			South Cheval.	Mid East Cheval.	South-East Cheval.	North Moderagam.	South Moderagam.	Kutiramalai Paar.
1905.								
February 20 ...	251	1,955,167	—	—	—	—	1,955,167	—
,, 21 ...	297	1,742,400	—	—	—	—	1,742,400	—
,, 22 ...	301	4,574,460	—	—	—	—	—	4,574,460
,, 23 ...	233	4,377,225	—	—	—	—	—	4,377,225
,, 24 ...	303	4,978,685	—	—	—	—	—	4,978,685
,, 25 ...	305	4,706,389	—	—	—	—	—	4,706,389
,, 27 ...	310	4,394,879	—	—	—	—	—	4,394,879
,, 28 ...	313	2,888,470	—	—	—	—	—	2,888,470
March 1	315	1,689,945	—	—	—	—	—	1,689,945
,, 2 ...	315	4,188,135	—	—	—	—	4,188,135	—
,, 3 ...	315	3,443,092	—	—	—	—	3,443,092	—
,, 4 ...	305	3,471,877	1,157,293	—	—	1,157,292	1,157,292	—
,, 6 ...	309	3,315,877	3,315,877	—	—	—	—	—
,, 7 ...	296	3,119,475	3,119,475	—	—	—	—	—
,, 8 ...	314	2,874,810	2,874,810	—	—	—	—	—
,, 9 ...	315	2,464,732	2,464,732	—	—	—	—	—
,, 10 ...	313	2,781,458	2,781,458	—	—	—	—	—
,, 11 ...	315	3,539,992	2,789,992	—	750,000	—	—	—
,, 13 ...	315	2,106,907	2,106,907	—	—	—	—	—
,, 14 ...	310	1,992,780	1,992,780	—	—	—	—	—
,, 15 ...	307	1,691,670	941,670	—	750,000	—	—	—
,, 16 ...	303	1,388,235	1,388,235	—	—	—	—	—
,, 17 ...	311	2,530,748	843,583	—	—	1,687,165	—	—
,, 18 ...	300	1,104,233	1,104,233	—	—	—	—	—
,, 20 ...	231	466,098	466,098	—	—	—	—	—
,, 22 ...	161	396,621	—	—	—	396,621	—	—
,, 24 ...	157	1,019,212	—	—	—	1,019,212	—	—
,, 25 ...	175	1,346,820	—	—	—	1,346,820	—	—
,, 27 ...	171	1,162,380	—	—	—	1,162,380	—	—
,, 28 ...	155	383,415	—	—	—	287,562	95,853	—
,, 29 ...	174	725,865	—	725,865	—	—	—	—
,, 30 ...	73	99,075	—	99,075	—	—	—	—
April 3 ...	93	336,502	—	336,502	—	—	—	—
,, 4 ...	104	555,547	—	555,547	—	—	—	—
,, 5 ...	102	441,690	—	441,690	—	—	—	—
,, 6 ...	101	578,130	—	78,130	—	—	—	—
,, 7 ...	99	349,192	349,192	—	—	—	—	—
,, 8 ...	91	137,946	—	—	—	68,973	68,973	—
,, 10 ...	68	264,712	264,712	—	—	—	—	—
,, 11 ...	92	298,590	298,590	—	—	—	—	—
,, 12 ...	96	318,720	79,680	239,040	—	—	—	—
,, 14 ...	16	41,168	40,013	—	1,155	—	—	—
,, 15 ...	83	185,130	185,130	—	—	—	—	—
,, 17 ...	78	259,402	259,402	—	—	—	—	—
,, 19 ...	34	196,290	—	—	—	196,290	—	—
,, 20 ...	47	158,962	—	—	—	54,127	104,835	—
,, 21 ...	12	73,282	—	—	—	—	73,282	—
,, 25 ...	—	975	—	—	975	—	—	—
	9,684	81,117,365	28,823,862	2,975,849	1,502,130	7,376,442	12,829,029	27,610,053

To these totals have to be added the number of oysters dredged by the ss. "Violet" from 30th January to 29th April, amounting to 635,210 from the South Cheval, 1,460 from the South-East

Cheval, 102,485 from the South Moderagam. The respective yield of the individual beds may be compared with the estimates thus:—

Name of Bed.	Total Number of Oysters landed.	Estimated Amount opened by divers (Minimum).	Balance left on Bank.	Inspection Estimate prior to Fishery.
South Cheval and adjoining part of South-East	29,383,444 ...	7,000,000 ...	10,000,000* ...	47,500,000
Separate part of South-East Cheval ...	1,503,590† ...	500,000 ...	10,000,000‡ ...	13,000,000
Mid-East Cheval	2,975,849 ...	750,000 ...	5,000,000§ ...	9,000,000
North Moderagam	7,280,817 ...	1,500,000 ...	1,000,000* ...	10,000,000
South Moderagam	12,931,514 ...	2,000,000 ...	4,500,000§ ...	19,700,000
Kutiramalai‖	27,610,053 ...	4,000,000 ...	8,000,000* ...	Not estimated
	81,876,520	15,750,000	38,500,000	

(*b*) Historical Note on the Sections fished.

The South Cheval and the two Moderagams have a record for fruitfulness superior to all other Ceylon banks. The former has yielded during the past seventy-seven years no fewer than nine fisheries; the latter seven. The South Cheval has provided fisheries in the years 1829, 1830, 1836, 1837, 1858, 1863, 1877, 1888, and now again in 1905, while the Moderagams have been fruitful in 1828, 1859, 1860, 1877, 1887, 1888, and 1905.

The Mid-East and South-Central Cheval have in comparison but an insignificant record, the present year's fishing ground having previously given oysters only in the years 1837, 1888 (doubtful), and 1903.

There can be no doubt that the South Cheval is the section possessing the greatest inherent or natural qualities suitable for the growth and well-being of pearl oysters in the whole of the Gulf of Mannar, but it is difficult to say precisely wherein such consists. Probably they lie in a combination of three factors—special abundance of suitable food material, a well-cultched bottom affording favourable holding ground, and a position sheltered in large measure from the violence of the south-west monsoon by the long tongue of Karativu shoal. The last-named has been put forward by some as a sufficient explanation in itself, but standing alone it is undoubtedly inadequate; other beds enjoying equal and even greater shelter have nothing like equal fertility. This, then, is the ground that unquestionably offers the greatest possibilities for the successful prosecution of cultural methods. The major portion of the area is in addition admirably suited for dredging, the middle and northern thirds being practically free from any obstructions; the southern third alone is somewhat difficult, but with the aid of a few mark buoys even this may be fished when necessary by the dredge.

With regard to Kutiramalai Paar, the name I propose to apply to the northern half of the sandy area lying between the South Moderagam Paar and Kutiramalai Point, I can find no reference to mature oysters having ever been fished or seen there; I cannot even trace any indication of the ground having ever been inspected, the area in question being blank in the inspection chart at present in use, although favourable ground closer to Kutiramalai Point as well as a muddy area within the mouth of Portugai Bay received attention.

This year's results emphasize once more the good grounds there are in favour of my contention that fisheries have been lost in the past through inadequate inspection. To cope with the

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* Much scattered, almost certain to disappear this year.

† This is the number which I estimate was filched by the divers from that portion of the South-East Cheval which was not meant to be opened to fishing this season.

‡ A solid bed, giving fair promise of remaining; the number certified by inspection subsequent to the fishery.

§ Divers will not fish these oysters on account of the abundance of associated young which have to be separated; the majority will die off this year.

‖ I propose to give this name, Kutiramalai Paar, to the area lying south of the South Modaragam Paar. It consists wholly of sandy ground, and has never previously been fished so far as I can ascertain.

uncertain distribution of spat-falls consequent upon the complexity and changeability of the currents over the pearl bank area, as well as to take account of the fact that the ground where spat-falls occur may vary from time to time in regard to its potentiality to bring the young oysters to maturity, necessitates periodical inspection upon the widest possible scale. The unlikely places must be examined equally with the likely, though naturally it will be proper to pay primary attention to the latter.

(*c*) The Progress of the Fishery.

The fishery began punctually as advertised upon 20th February, falsifying the belief hitherto prevalent that it is hopeless to expect divers to attend until the first week of March. The abundant promise of specially lucrative fishing, coupled with the knowledge that from 1,000 to 2,000 Arab divers were either at the camp or on the way thither, influenced the Kilakarai and Tuticorin men to depart from the trammels of old habits, and by 19th February it was seen that vigorous fishing was assured from the date specified. Still it was with considerable astonishment that I saw at daybreak of 20th February a fleet of 251 diving boats anchored round the inspection barque, the men eagerly awaiting the moment when the mounting sun should be sufficiently high to justify the firing of the signal gun for the commencement of the day's work.

The bank opened to fishing on the first day was the south half of the South Moderagam Paar properly so called. The greater bulk of the oysters thereon were covered with young some six months old ; these the divers avoided as far as possible, but I was pleased to see that separation was carried on whenever the boats anchored on such ground, the young being thrown back into the sea. In spite of this difficulty the day's catch amounted to 1,955,377, by far the highest total on record for an opening day. The next day the number of the boats engaged rose to within three of 300 ; the catch, however, was reduced owing to the delay caused by the necessity to separate the young oysters from the old.

On 22nd February a considerable number of boats fished on the ground to the south of that portion of the South Moderagam inspected earlier in the month. The whole of this area is composed of purely sandy bottom whereon lay oysters free from commingling with any of a younger generation ; all were a little over three years old. In some places they lay in loose bunches ranging from five to twelve individuals in each ; elsewhere the oysters clung to the projecting edges of large wedge-shaped shells of *Pinna bicolor*, rooted upright in the sand by the narrow end. The former condition delighted the hearts of the divers ; the latter gave those unprovided with protecting finger-stalls considerable trouble, the sharp edges of the Pinna shells inflicting frequent cuts and scratches on the hands tearing them from their sandy foothold. In both cases the divers filled their bags with remarkable celerity, forty seconds in many cases sufficing to fill the diver's bag with 60, 70, and even 100 oysters. As a result the day's catch, aggregating the enormous total of 4,574,460 oysters, broke every known record. Light wind made progress to the shore slow, the boats straggling along in loose order ; many had to use paddles, and one sighed for the assistance of a couple of powerful tugs, whereof the cost, to say nothing of the convenience, would be covered time and again by the safeguard this help would be against illicit opening of oysters, a malpractice which flourishes especially on days when the run to land is unduly prolonged.

Work on this sandy area continued with feverish activity for the remainder of the week. The daily catches never fell below 4,000,000 per day, while on 24th February high water mark was reached with the enormous take of 5,005,685 oysters. Such a huge total for one day's fishing establishes a record that is likely to remain unsurpassed for many years to come.

The loads taken ashore each day showed no great falling off till the last day of February, when indications began to point to the impending exhaustion of the bank ; the next day there was further reduction, the total for 295 boats being little over 1½ million.

In consequence I opened a fresh section of the bed on the north side of the South Moderagam. Oysters there were plentiful, but the area being circumscribed I was not surprised to find that two days' strenuous fishing sufficed to cream the bank.

For some days previous to this the divers, rendered greedy and exacting by their initial good fortune, had had their thoughts and desires fixed on the South Cheval bed as their land of promise, and on 4th March, taking advantage of a temporary absence of the patrol steamers, they scattered northwards, a third of their number on the North Moderagam and a third on the South Cheval. Accordingly, as the North Moderagam oysters were relatively poor in pearl yield, it was considered expedient to postpone fishing that bank and to open the South Cheval, for which the merchants as well as the divers were clamouring.

Sunday, 5th March, I spent in marking out the fishing boundaries with lines of bamboo buoys bearing red flags, while the centre of each of the chief oyster patches was marked by a white flag as in last year's fishery. The following day saw all the boats at work on the South Cheval, and for four days the work proceeded smoothly, the men giving little trouble.

This bank greatly disappointed the divers, who, being accustomed to the easily gathered loose oyster bunches of Kutiramalai Paar, did not appreciate the trouble entailed in wrenching the oysters individually from the rock, the condition wherein they are found on the South Cheval. Superior quality was little or no compensation in their eyes; their ambition is always quantity rather than quality. A flagrant instance of this occurred about this time. On 9th March one diving boat anchored on that patch of the South-East Cheval lying separate from the South Cheval bed; the men subsequently reported to their comrades in the fleet that the oysters there lay in bunches. The next morning the whole fleet settled down with one accord on the South-East bed, and it took two hours of incessant objurgation to get them away and back to the proper fishing ground. The Arabs, I must say, behaved best, while the Kilakarai Moormen were the most troublesome, making but a pretence of discontinuing work when remonstrated with, re-commencing diving immediately the launch passed on. As a consequence of this invasion of a bed of oysters of inferior pearl yield the prices fell from Rs. 65·73, given on 9th March for South Cheval oysters, to Rs. 38·16 for those of the succeeding day on account of the admixture with these South-East Cheval ones.

Discipline in the fleet once broken was thereafter difficult to maintain, the men quickly grasping the fact that the fleet was too large to be effectually controlled by the means at my disposal. There was for a week thereafter a continual game of hide-and-seek proceeding, the boats watching for any chance to pass beyond the boundaries set to their labours, while I, on my part, was kept on continuous patrol driving trespassers away from the forbidden ground. Eventually the divers gave in, finding the loss of time they sustained in this conflict insufficiently compensated otherwise.

Varied with the excitement attendant upon these occasional excursions, fishing on the South Cheval proceeded prosperously till 18th March, the last day whereon 300 boats participated in the fishing.

The weather hitherto, while not strictly typical "pearl-fishery weather," had been well suited to sailing and diving requirements. On 18th March conditions changed, marked by a south-west swell with wind from the same quarter. By next fishing day, 20th March, the disturbance had gathered considerable force, rendering diving so difficult and arduous that, although 231 boats came out, the day's catch totalled less than half a million oysters, a number surprising indeed to those who watched the acrobatic performances of the boats when at anchor; by noon the wind and sea appeared to be increasing, when, feeling anxious for the safety of the fleet, I gave the signal to cease work and sent the launches to help those of the boats that were crippled.

It is under conditions such as these that the attendant launches prove their value; on this occasion a divers' boat having capsized, with the timely assistance of the ss. "Active," which I sent to render help, the men were all saved and the dhoney towed to Marichchikkaddi. Accidents to the rudder are the most frequent of the minor damages entailed by a rough day on the banks, and

during the latter half of the fishery it was no uncommon occurrence for the launches to have from two to five of these crippled craft to tow to port.

From this time forth work was carried on with increasing difficulty; owing to the changeable and frequently boisterous weather, the working of the fleet became intermittent and punctuated with idle days spent in port. 18th March may be counted as marking the end of the fishery proper. The great bulk of the oysters had then been removed, and influenced by this and the unfavourable nature of the weather a third of the boats took their departure. Proceeds thereafter never once reached Rs. 27,000, whereas prior to this date the lowest had been over Rs. 49,000.

The South Cheval being creamed, fishing on the North Moderagam Paar was begun on 22nd March, and was continued with fair success both as regards quantity of oysters and prices realized for four days—a high sea running the while.

The last section to be fished was the bed on the south side of the Mid-East and South-Central sections of the Cheval Paar. Fishing there commenced on 29th March, when 174 boats lifted a quarter of a million oysters from the south side. The weather that evening again became stormy, the inspection barque continually dragging her anchor during the night, pitching and rolling so violently that sleep became an impossibility. So bad was it that my astonishment was great to see 73 boats struggle out at daybreak; the weather was absolutely unfit for them both as regards safety and utility. The Government share on this day amounted to a paltry 66,000 oysters. The launches again did excellent work, towing being an absolute necessity, as many of the boats were unable to beat against the wind and were in danger of driving ashore at Kallar.

Three days of idleness followed marked by another exodus of divers, who, with plenty of money in their possession and because of the hardship of their work under the prevailing adverse weather conditions, were now careless whether the fishery continued longer or not.

Our weather prophets had, however, prophesied a change for the better three days before new moon; sure enough on 3rd April, two days prior to that phase, the sea and wind so improved that fishing was resumed. This and the next succeeding day sufficed to remove the bulk of the oysters on the Mid-East that were not masked by the presence of myriads of a younger generation, and which the divers virtually refused to fish.

For the remainder of the fishery the boats were engaged in gleaning over the whole ground already fished; from the heavy loads taken when good fishing weather prevailed, it is evident how unevenly and imperfectly fishing proceeded so long as the full fleet of over 300 boats were at work.

With the renewed onset of high wind from the south-west on 19th April, the tindals of the diving boats began to raise objection to putting to sea, and chiefly on this account the fishery came to an end on 21st April, when eleven diving boats were all that came out. The fishery ended sixty days from the opening on 20th February; fishing actually proceeded on forty-seven days, constituting thereby one more record to the credit of this phenomenal fishery.

Illicit opening of Oysters; the extent and the remedy.

There is not the slightest doubt that great numbers of oysters were opened by the divers and manduks and even by the "boat-guards" on the run home, especially on those days when calms and light airs gave several hours of unrestricted freedom wherein such malpractice could be carried on with ease and celerity.

During the 1903 fishery there were opened, according to Captain Legge's estimate, no fewer than 9½ millions of oysters, against 41 millions landed and accounted for at Marichchukkaddi. From the personal knowledge I have of the fishery in question, I believe this estimated loss of 23 per cent. to be by no means exaggerated. The percentage this year has been, I consider, somewhat less; it was however variable, greater on the banks further from shore and on those where the oysters were difficult to gather.

On Kutiramalai Paar it was comparatively slight. Prices were good considering the age and the abundance of oysters there, while the bank was within seven miles from the camp. It paid the divers better to sell these oysters than to open and steal the pearls. I do not think that many more than 4 millions were opened on this bank, as against the 30 millions taken ashore.

Contrary conditions prevailed on the South Cheval. On that bed there was a considerable, though variable, admixture of valuable 5 to 6-year old oysters very rich in pearls; the bank was some miles further from shore, and the oysters were troublesome to gather, the majority being firmly attached to rocky patches on the sea bottom. I estimate that some 25 per cent. of the oysters fished there were opened on the run home, certainly not less than 7 millions, and probably a good many more. The loss sustained by Government is, however, far from limited to the loss of its two-thirds share of such illicitly opened oysters; the divers choose the largest and oldest individuals for their operations, and as the great majority of the best oysters are thus weeded out of the day's catch, the remainder, which goes to the Government kottu, is depreciated greatly in value. This the merchants are well aware of, and it is this knowledge that induced them willingly to give much higher prices for oysters dredged by the "Violet" than they would give for oysters from the same locality fished by the divers; the buyers knew that the former were exactly as brought up, that no tampering with them had taken place, and that therefore each bag contained its due proportion of large oysters.

An incident connected with the confiscation of a boat load of oysters on 4th April first showed me with what deliberate method some at least of the divers pursue this operation. The boat in question had fished beyond the boundary line and had disregarded all warnings; at 11 A.M. I had it brought alongside the barque and the oysters removed and provisionally confiscated. The oysters were found disposed partly loose and partly in bags. To ascertain the number taken, the bags had to be emptied, and as the bagged oysters formed one heap and the loose ones another, a difference in the size of those in the one from those in the other was obvious to the most casual observer. The inference was clear that the smaller oysters, which had been packed neatly in bags, were intended for the Government kottu, while the large ones lying loose were intended for opening on the run home.

The best practicable safeguard that I can think of is to provide one or two powerful tugs to tow the whole fleet to port as soon as diving has ceased at 1 P.M., the men being made to lie down on the decks of their boats during the whole time. The cost would not be excessive, for even the "Violet," a vessel not designed for such work, is able to tow fifty diving boats at one time. She actually did tow thirty-nine on one occasion, and there was ample power available to have taken another eleven.

If either the "Goliath" or the "Samson" can be spared at the time of the next fishery, I strongly recommend employment on the duty indicated; the saving or profit would be so high as to be wholly out of all proportion to the cost involved. As above-mentioned, I believe the number of oysters opened during this fishery to have exceeded 15,000,000. If, however, it has not been more than 12,000,000, and we make first an allowance of 3,000,000 for the number which might still, in spite of this precaution, be opened illegally, and then from the remainder, 9,000,000, deduct the divers' share of one-third, we still have a total of 6,000,000 oysters, which at the lowest computation might have been added to the Government share had provision been made for the towage of the fleet from the banks to the camp. 6,000,000 oysters at Rs. 50 per 1,000 (roughly the average price at the fishery) would amount to Rs. 450,000, to which must be added the enhanced value of the general catch consequent on the greater proportion of large oysters left among the oysters landed, and the wages which otherwise would be paid to boat-guards.

I have no faith in the employment of boat-guards of the class hitherto employed. They are venal, I believe, without exception, and this perhaps cannot be wondered at considering that their pay is but Re. 1 per diem, and that a contribution of 50 cents from each of the fifteen divers—a low

average per boat—means a bribe of Rs. 7·50 per day. The pay of boat-guards during the present fishery cost approximately Rs. 9,000 per month, which of itself would go far to pay the expenses of a powerful tug of the "Samson" class.

(*d*) Casualties.

It is satisfactory to record that this fishery was marked by immunity from any fatal accident, contrasting favourably with its predecessors of 1903 and 1904. A half-breed Arab diver had, however, a very narrow escape; he collapsed while on the bottom, and was not drawn up by his comrades for some minutes. He was taken to the inspection vessel thereafter, and in my temporary absence Lieut.-Col. K. M. Foss took charge of the case; his long-continued and persistent efforts to restore animation were successful, and when we eventually gave him back wrapped in a blanket to his friends we had the satisfaction of knowing that he was in a fair way to recovery. He certainly owed his life to Col. Foss.

Another day an Arab came aboard suffering from the effects of a wound in the thumb inflicted by the poisonous spine of a small fish. The hand and forearm were considerably swollen, and the man appeared to suffer great agony. Knowing the beneficial effect of permanganate of potash as an antidote in the case of snake bites, I had the small wound slightly enlarged and introduced therein a crystal of this substance. The result was quite satisfactory; the pain and swelling rapidly subsided, and after an hour's rest the man asked to be sent back to his boat in order to resume diving! Before he went he begged to be given a few of the magical crystals.

Other accidents occurred through boats colliding while fishing; the wonder was that such were not more numerous. In spite of rough weather towards the termination of the fishery no fishing boats were lost; a few capsized, but such were salved and the men all rescued. In the towage of the boats during rough weather the tindals of both the "Nellie" and the "Active" behaved very well; indeed, I wish to record my particular satisfaction with the tindal of the "Nellie," who exhibited excellent initiative and energy in the performance of the duties assigned him.

(*e*) The need for Fishing Regulations.

The unwritten laws of custom have hitherto ruled the operations of the divers when fishing on the banks; such were perhaps adequate when the fleet was restricted in its numbers, and when divers from distant parts did not participate. But the old order changeth or rather should change in accordance with new conditions, and during the fishery under review I found the difficulties incident to the management of the work on the banks rendered unnecessarily troublesome by reason of the want of a code of simple rules for the regulation of the diving operations.

What I consider as desirable is the issue of printed instructions in English, Tamil, and Arabic defining the rules which the owners and tindals of the diving boats shall observe at sea while under the control of the Inspector of Pearl Banks; the consequences that shall follow disobedience of these rules should also be stated, in order that the men shall be aware what penalties may accrue if they be contravened.

(*a*) *Numbering of the boats.*—In these instructions the men should be informed how and where to display upon the sail and upon the hull of the boat the fishery number allotted to their craft, with the penalty for neglect in either particular. (The numbering of the boats at this fishery was carried out in so slovenly a way that many numbers were undecipherable, while others were obliterated wholly or in part within a couple of days from the opening of the fishery.) Under the present absence of system it is in practice impossible to check the numbers of those boats that take up fishing.

(*b*) *Fishing beyond limits.*—Particulars of the method adopted by the Inspector of Pearl Banks in the marking of the fishery limits by means of flag buoys should be detailed; power to inflict summary punishment in particularly flagrant cases of disobedience in fishing outside the

boundaries should, I consider, be given to the Inspector, the nature and extent of the punishments being defined if thought necessary. It is of the greatest importance that punishment for disregard of boundary limits should follow swiftly. My experience this season has shown clearly that the men in many cases were willing to take the risks when they found that my power extended no further than the report of their conduct to the Government Agent. It is obvious that a penalty exacted in full sight of their comrades immediately upon the commission of an offence has salutary effects that are wanting from punishment deferred and inflicted amid the turmoil and distractions of "Pearl Town."

(*c*) *Daily verification of the numbers of the boats engaged in fishing.*—The present absence of system renders it, in practice, impossible to check day by day the fishery or register number of each boat engaged in fishing; it is difficult therefore to be assured that no boats without passes are at work. Such an occurrence as the latter I can scarcely imagine ever to happen, but if no check exists a premium is offered to adventurous spirits to attempt such a flagrant act of poaching. The further advantage accrues from daily verifying the registration of all boats that, if the tindal of each is bound to report arrival to the Inspector, the latter has better control of the boats' movements and can issue to the tindals any special directions necessary from day to day. I recommend therefore that besides the numbering on the hull, the fishery number of each boat be painted on a loose square of cotton which shall be sewn to the sail in such position as may be directed by the Inspector. The size and colour of the figures should at the same time be specified. This being done at the time each boat first joins the fishing fleet, the tindal should be ordered by the fishing rules, before beginning each day's diving, to sail past such specified point or points at the rendezvous upon the fishing ground as the Inspector may decide upon and notify from time to time. At each of these points an inspection boat in charge of a Government coxswain would be stationed, and as each diving boat passed, displaying its number conspicuously, the coxswain would note the same. At the close of the day's fishing the Inspector would make up a list of boats thus checked and despatch it to the Superintendent ashore, who by comparing this with the list of boats which return from fishing would be able to trace any discrepancy, should there be any.

(*d*) *Towage.*—Rules might well be framed to obviate the unnecessary trouble that is frequently occasioned to the launches when about to take diving boats in tow by the indifference of the men aboard the latter to the need to put their boat in a proper position and their neglect to help in the operation. On several occasions during the past fishery the boats were manœuvred to cross the path of the steamer, and when right across her bows sail was lowered and the steamer had difficulty to avoid a collision, the crew of the diving boat standing idle the while. Further, each boat should be required to carry a lantern, to be lit after dark should calms or contrary wind prevent her making port before sunset, in order to serve as a guide to the patrolling launches sent to render assistance.

(*e*) *Accidents.*—Any accidents or illness that may occur should be reported to the Inspector with the least possible delay, especially in the case of men who have collapsed while under water. Delay in the latter instance is practically certain to be fatal to the subject, whereas if reported at once aboard the Inspector's ship measures would be taken immediately to restore animation.

(*f*) *Cessation of fishing.*—Ready obedience to the "cease work" signal should be exacted, the Inspector being given power to cause the rule to be respected. Dilatory observance of this signal frequently occasions the waste of much of the time of the attendant launches, which have to be sent round to hasten the movements of laggard boats, thereby detaining them from other more important duties.

(*f*) The Weather during the Fishery.

True north-east monsoon conditions still prevailed at the time of our departure from Colombo on 26th January, and the strong northerly winds made progress slow on the journey to Marichchukkaddi. From 21st January until 20th February similar winds continued, blowing from

north and north-north-east in the morning, veering to north-north-west and north-west in the afternoon.

Cessation of these steady northerly winds coincided with the opening of the fishery on 20th February; thenceforward for a duration of two months there prevailed the usual inter-monsoon period of variable wind currents. This seasonal interval, while it extended to greater length than it did last year, was noteworthy for the frequency with which spells of rough weather interrupted fishing, and which repeatedly gave rise to the fear of an unexpectedly early oncome of the south-west monsoon. The latter did not set in, however, till 18th April, from which date the wind blew continuously from the south-west, accompanied by a more or less heavy swell from the same quarter.

The particulars of the inter-monsoon period are so variable that they may best be set forth in diary form as follows :—

Period. 1905.	Character of the Weather.
February 22 to March 1	... Alternate land and sea breezes, with rain squalls on the afternoons of February 22 and 23.
March 2 to 11 ...	... Continuous northerly breezes ranging from E.N.E. through N. to N.N.W.
March 12 to 14 ...	... The wind from S.W. and W.S.W., accompanied by a heavy swell from the S.W.
March 15 to 17 ...	... Resumption of land and sea breezes; general fine weather.
March 18 to April 2	... South-west conditions prevailed throughout this period with rough weather, save on March 27 and 28, a heavy S.W. swell the whole time. Fishing was greatly interfered with.
April 3 ...	... The native weather prophets foretold that about three days before full moon (April 5) an improvement in the weather would take place; sure enough on April 3 there was cessation of the S.W. winds experienced continuously during the fortnight preceding, with a reversion to land and sea breezes and calm from 10 A.M. till noon.
April 4 to 17 ...	... A period of excellent fishery weather so far as the mornings were concerned marked by the prevalence of light winds and calms which made diving easy. The lightness of the wind hampered greatly the arrival and the return of the fleet, and on several occasions the boats did not reach the camp till after sunset; indeed, a considerable number of those engaged in fishing on April 12 did not return to port till 10 A.M. the succeeding day, the boats having drifted a considerable distance up the coast. In the mornings during this period the wind came generally from the E.S.E. and S.E., veering gradually round to W. and S.W. in the afternoon, with dead calm at noon and in the early afternoon. Rain squalls from the N.E. were frequent in the afternoons, and during this period the fleet ceased work each day soon after midday in the hope of getting to shore before the advent of these squalls. They seldom succeeded.
April 18 and onwards	... South-west monsoon conditions of wind and swell. Weather generally fine.

(*g*) Surface Drift.

When we left Colombo on 26th January we experienced a fairly strong current setting to the southward, retarding our progress considerably. Throughout February and until 11th March it ran steadily in the same direction, gradually weakening till with the advent of southerly winds on 13th March it changed direction and ran to the northward. It so continued the next day, but on 15th and 16th March it was so weak that wind and tide made the direction extremely variable.

From 17th March to 2nd April the current ran towards the north with strength, accompanied by a heavy swell. South and south-east currents prevailed from 3rd to 7th April, while from the 8th to the 17th of the same month the drift was notably variable and usually of little or no force. From 18th April onwards a current setting to the north prevailed, gradually gaining in force till on our return towards Colombo on 1st to 3rd May its strength must have been fully two knots per hour.

So far as I know there was no spat fall from the oysters during the period of weak and variable currents in March and April; the only oyster spawn shed this year (Eastern Cheval), I judge from its size, was liberated from the gonads between the middle of January and the middle

of February. At this time the current was running to the southward in the locality of the Ceylon pearl banks.

Abstract of Observations on Surface Drift.

Period.	Direction of Drift.
January 26 to March 11	... To the south ; strong.
March 13 to March 14	... To the northward ; weak.
March 15 to March 16	... Variable ; weak.
March 17 to April 2	... To the north ; moderately strong.
April 3 to April 7	... To the south and south-east ; weak.
April 8 to April 17	... Variable ; calm.
April 18 onwards	... To the north ; increasing rapidly in strength.

An occurrence worthy of record in connection with the investigation of surface drift in these waters arose through the drifting from position of one of the flag buoys placed on the Cheval Paar on 7th February. This particular buoy, which had two red pennants attached, appears to have been too lightly weighted, and disappeared from the bank immediately after being placed. The next heard of it was from a report made by the Master of the ss. "Ranza" that he observed a "bamboo upright, about 20 ft. high, with two new red pennants attached in lat. 8° 3′ N. and long. 73° 51′ E." The "Ranza" arrived in Colombo on 16th March, and we may infer that the bamboo was sighted on the 14th or 15th of the same month, thirty-five or thirty-six days after being placed on the Cheval Paar. As its original position on the latter was lat. 8° 42′ N. and long. 79° 48′ E., it travelled approximately some 364 nautical miles in thirty-six days, or ten knots per day. The place where the pennants were seen by the "Ranza" was about 3° 41′ west of the meridian of Cape Comorin and almost due west thereof, so it would appear that after travelling southwards towards Colombo for some time the bamboo came within the influence of a strong current setting westwards in the direction of Minicoy.

III.—THE DREDGING OPERATIONS OF THE SS. "VIOLET."

(*a*) Account of the Work accomplished.

When reporting upon the results of the pearl banks inspection of November, 1904, reference to dredging operations was purposely omitted, as it would have been premature to attempt to draw conclusions from the scanty data then available.

After the fishery of 1904 the intention was to re-employ the ss. "Ready" for the purposes of further oyster dredging, if it were found possible to effect certain radical alterations affecting the hold and deck plan to allow of the provision of additional dredging equipment. The requirements of the Harbour Works Department, the owners of the steamer, were however such as to preclude these alterations, and thereby to bar her further employment on pearl fishery duties. The Government, desirous to give the oyster-dredging scheme a fair test, had therefore to look elsewhere for a suitable vessel, and thus it was that the suitability of the steam-trawler "Violet" came up for consideration.

This vessel belonged at the time to Mr. T. A. J. Noorbhai of Colombo, who had brought her out some two years previously with a view to the introduction of fish-trawling in Ceylon waters ; unfortunately for Mr. Noorbhai a variety of causes, not, however, due to any lack of good trawling ground, led to the abandonment of the enterprise, and the vessel at the time I refer to was on the market for sale. The vessel is a typical North Sea trawler, built for a Grimsby firm in 1896, and was fully as readily adaptable to dredging purposes as any trawler that could have been obtained at the time in England.

The real choice lay between taking this steamer, and thereby having her at our immediate disposal, or of sending to England to have one built to special design.

The advantages of the former course are abundantly manifest, as a steamer built to order would not have reached Ceylon in time to take part in the fishery of 1905, far less in the November, 1904, inspection. Besides this, as was pointed out by Mr. E. B. Denham, whose sympathetic assistance

and well-considered advice in this matter, as in all others connected with pearl fishery work, have been of the greatest support to me, while the "Ready's" experiments had shown us the general lines upon which the design for special fittings should be based, many details were yet doubtful. He dwelt specially on the advantages to be gained by taking a vessel that was available for work during the approaching inspection and fishery, when we should have ample opportunity to test the various special improvements in equipment and arrangement which I contemplated introducing. It was not as if steam dredging on the scale proposed and under the special and peculiar local conditions prevailing in pearl fishing in Ceylon had ever before been tested; the work would be unique in character, and we could not expect marine architects at home to furnish a suitable design; the main lines must be elaborated in Ceylon, and for this further experiments were necessary. Because of these reasons the ss. "Violet" was eventually purchased by the Government, the price being Rs. 50,000, a reasonable enough one considering that the vessel was immediately available and generally in good and serviceable condition.

The dimensions and the particulars of construction are as follows:—

Length between perpendiculars	95 feet
Breadth	20 feet 6 inches
Depth	11 feet
Draft laden	12 feet
Tonnage	150 gross, 57 nett
Speed	10 knots
Coal consumption	3½ tons per 24 hours
Cargo accommodation	About 150 tons

The engine is of the triple condensing marine type of 40 horse-power nominal.

The principal alterations which were carried out at my suggestion consisted in the fitting on either side of four dredging davits with their necessary fairleads and the provision of a second steam winch. Each winch was to wind in two dredges at each haul, thereby allowing four dredges to be used at one time, the same number as used on the "Ready." I was also desirous of operating some from the stern of the vessel, but as this would have necessitated the fitting of a steam capstan requiring several extra weeks for construction, such had to be postponed for the time being.

Mr. C. H. S. Jelstrup was appointed to the post of Master on 1st October, 1904, and twenty-five days later the vessel left Colombo for the pearl banks.

The beginning was sufficiently discouraging, two separate outbreaks of fire occurring in the bunkers during the first fortnight's operations, each of which compelled a return to Colombo with consequent loss of a valuable portion of the available fine weather, as well as involving considerable unremunerative expenditure.

The most important section of the dredging scheme is the transplantation of young oysters from unfavourable to favourable situations on the banks; in November, 1904, this was found to be temporarily unnecessary, as an immense spat fall had taken place over nearly the whole of the Cheval Paar and over part of the South Moderagam. I was thereby enabled to utilize the steamer to dredge mature or fishable oysters for the sake of the contained pearls. From 7th November to 17th December, the date when stormy weather compelled a retreat to the harbour of Colombo, 322,468 oysters were dredged and delivered to Mr. G. G. Dixon to be treated by his patent oyster-washing machine. This number was, I consider, fairly satisfactory, seeing that the crew were new to the work, and that the Master had to grope his way after success, as he had had no previous experience in dredging, and had only my instructions for his guidance.

During the progress of the operations I gave very careful attention to the working of the gear, and on my return from the banks early in December, 1904, I submitted a scheme for further alterations, and for the provision of considerable additions to the equipment with a view to increase materially the dredging capacity of the vessel. The chief of these suggestions were the installation of a steam capstan aft, the addition of two sets of dredging gear at the stern, of two additional on the quarter, and of a number of larger and heavier dredges. The Government treated the report in

the most liberal spirit possible ; the whole of the recommendations were sanctioned and ordered to be put in hand immediately. Mr. J. H. Rhodes was also appointed as dredging mate to lighten Captain Jelstrup's responsible and arduous labours.

I am glad to be able to record that the alterations were amply justified by results, the daily takes being doubled and even trebled during the subsequent dredging operations, increasing steadily day by day as officers and crew gained in experience, till during four days towards the close of the period wherein the vessel was engaged in dredging mature oysters for sale purposes, the average was 34,774 per day, reaching 38,250 as the maximum for one day's catch. Annexure No. VII. gives a statement of the daily progress of the work during the period when the vessel was engaged exclusively in dredging mature oysters, while the succeeding table (Annexure No. VIII.) furnishes a record of the quantities of mature oysters fished incidentally during the course of transplantation operations, together with the prices and proceeds of such as were sold.

On 15th March enough of mature oysters had been removed by the divers from the central portion of the South Cheval to permit of the commencement of operations for the establishment there by transplantation of a bed of young ones. Accordingly, I instructed Captain Jelstrup to dredge for young oysters aged about six to seven months, which I knew to be in profusion on the South Moderagam Paar, to convey them to the South Cheval and there to throw them overboard within the limits which I defined by a series of mark buoys.

The method adopted was to bag all the young oysters taken, to keep them in a cool place covered with wet sacks, and to steam twice a day, noon and evening, to the South Cheval, throwing them out as the vessel manœuvred between the flags. The young oysters stood the treatment well ; there was practically no mortality, as I ascertained by sending divers down from time to time to ascertain the condition of these young and to bring me samples.

The total quantity transplanted was upwards of ten millions. I propose to concentrate attention upon this bed during the next season, in order to give the experiment fair treatment. I hope to transplant thereto in November next an additional 10 to 15 millions ; after that we may hope that enough work shall have been accomplished to ensure a small fishery two years later—a result that would be due entirely to cultural methods, and not to the fortuitous interaction of currents and other natural influences.

During the course of the dredging a great amount of good was done by the capture and destruction of large numbers of starfishes and carnivorous gastropod molluscs, noted enemies of the pearl oyster. Frequently between 200 and 300 starfishes were taken and destroyed in one day. By my instructions these were retained on board for twenty-four hours in order to insure that life should of a certainty be extinct when they were returned to the sea.

Chanks.

A considerable number of chanks (*Turbinella rapa*) were dredged from the South Moderagam Paar, confirming my opinion that the dredge may be used to great advantage in chank fishing as well as demonstrating the presence of a chank bed between Marichchukkaddi and Kutiramalai. The shells obtained were sent ashore periodically, and were sold by auction at the close of the fishery. There were, in addition, considerable numbers taken ashore by the divers during the time the Moderagam Paars were being fished ; little groups of three or four laid out for sale were familiar objects in the by-ways of the camp.

(*b*) Financial Results of the Dredging Operations.

Turning now to the financial aspect of the dredging operations subsequent to the acquisition of the ss. "Violet," I am confronted with the initial difficulty that by far the greater part of the oysters dredged were not offered for sale publicly, being supplied to Mr. G. G. Dixon to experiment with in his oyster-washing machine, and that no particulars are available yet of the proceeds realized from the sale of the pearls obtained from such oysters. In any case Mr. Dixon's work was in itself

experimental, and may or may not be financially more profitable than open sale of the oysters. The profit and loss account of the dredging should certainly not be subjected to the hazard of the machine washing being unduly expensive or otherwise unsatisfactory; the most satisfactory and simplest plan will be, I consider, to take the average rate per 1,000 of the dredged oysters actually sold at auction, and to value the remainder at a similar rate. If anything, this will under-estimate the money returns that would have resulted from open sale, as the dredged oysters supplied to Mr. Dixon were of a finer quality, and contained a larger proportion of pearls than did those dredged ones which were sold. In the former case the oysters were from the South Cheval, in the latter from the South Moderagam. The former sold during the fishery at the average price (approximately) of Rs. 62 per 1,000, the latter at Rs. 42 only. From this it will be seen that as I credit the "Violet" for her catch on the South Cheval at the rate of the average for the inferior oysters of the South Moderagam, I am in reality under-stating the value of the dredged oysters by Rs. 20 per 1,000 oysters on the amount fished upon the South Cheval, namely, 977,563, which number at Rs. 20 per 1,000 gives a total under-valuation of, say, Rs. 19,550.

During the latter part of the fishery, when the dredged oysters were offered for sale in the same way as those obtained by the divers, it is of importance to note the great partiality shown by the merchants for those furnished by the "Violet." An average of fully Rs. 20 more per 1,000 was maintained consistently. The reason was that the dredged oysters being bagged under European supervision, buyers could rely that no illicit interference had occurred, such as is normal in the case of those sent in by the divers. As explained in my report on the progress of the fishery, it is the regular custom of the native divers to select the largest and most likely oysters for the purpose of opening during the run homewards after the cessation of diving.

The cost of dredging oysters also compares most favourably with that of the share system in vogue with divers. During the recent fishery it certainly did not exceed 20 per cent., as against the $33\frac{1}{3}$ per cent. of the divers' one-third share. But in reality the divers' share is close upon 50 per cent., when we make allowance, as we ought, for the great proportion of the finest oysters opened by the divers before they reach the shore. Dredging is economically a more sound method of fishing than is diving, and I look forward with increasing confidence to the developments it promises as gear and methods improve; both are capable of great and material improvement.

The picture of the ideal fishery steamer that I should like to have the opportunity to design is often before my eyes: a steamer capable of dredging 100,000 oysters per day during a fishery, and of transformation into an efficient steam-trawler when pearl fishery operations are at a standstill. Such a craft should ensure pearl fishing upon such economical lines as would hugely enhance the profits derivable from a fishery.

From the following particulars of the expenditure to date and of the valuation of the oysters dredged and other work done, the favourable financial outcome of the experiment is clearly demonstrated:—

A.—Abstract of Expenditure upon ss. "Violet."

Capital Account.		Rs.
Purchase price of the vessel and gear		50,000
Repairs, alterations, and additions to equipment		17,382
Total capital expenditure ...		67,382
Current or working expenses (wages, coal, stores, and minor repairs) for the seven months, from 1st October, 1904, to 4th May, 1905		23,803
Total amount at debit of the ship	Rs.	91,185

NOTE.—The working expenses were under Rs. 1,500 per month for the five months spent in commission, equal to Rs. 160 per day at twenty-five working days per month. At 35,000 oysters per day the proceeds at Rs. 70 per 1,000 amount to Rs. 2,450 obtained, as seen above, at a cost of Rs. 160. The same quantity of oysters fished by divers would cost at the least Rs. 816, a difference in favour of dredging on this comparatively small quantity—one day's work—of at least Rs. 656.

B.—Abstract of Earnings of the "Violet" from 1st October, 1904, to 4th May, 1905.

Dredged Oysters.			Rs.	c.
Proceeds of 104,060 sold at auction at an average price of Rs. 71·81 per 1,000 (excluding those dredged after close of fishery)			7,183	0
Estimated value of 977,563 oysters delivered to Mr. Dixon at the same rate as the auctioned ones, viz., Rs. 71·81 per 1,000			70,198	80
		Rs.	77,381	80
Other Services.				
Towage of diving boats on several occasions to and from the banks, say three days at Rs. 160 per day ...	Rs. c. 480 0			
Towage of the barque to and from Marichchukkaddi in January and May respectively, four days at Rs. 160 ...	640 0			
Laying out buoys and towage of barque on bank during absence of the "Serendib," five days at Rs. 160 ...	800 0			
			1,920	0
Total of estimated earnings		Rs.	79,301	80

NOTE.—No credit has been allowed for the transplantation, from which great eventual profit is due.

C.—Comparison of Expenditure and Earnings.

	Rs.	c.
Capital expenditure	67,382	0
Working expenses	23,803	0
Total of expenditure	91,185	0
Amount of earnings as above	79,301	0
Balance, being the total amount at the debit of the ship on 4th May, 1905 ...	11,884	0

The foregoing figures show that the earnings of the vessel during the short time she has been at work, after paying off the working expenses, are sufficient to reduce the capital charge from Rs. 67,382 to Rs. 11,884. If the vessel were to become a total loss to-day, the actual sum lost would be represented by the latter amount.

That Rs. 79,301 should be earned during less than five months of actual work upon a gross expenditure of Rs. 91,185 and a capital sum of Rs. 67,382, is a profit large enough, I think, to satisfy the most captious of critics. The knowledge of such success is, I hope, very gratifying to Mr. E. B. Denham, who shared with me the responsibility involved in an advocacy of the purchase of the ss. "Violet." I should add that the earnings, Rs. 79,301, after deduction of the working expenses Rs. 23,803, and depreciation at 15 per cent. per annum on Rs. 67,382 for seven months (Rs. 5,900) give a nett profit of Rs. 42,000, equivalent to a profit of nearly 75 per cent. for less than five months actual working, part of which was employed upon transplantation, for which no credit is taken in assessing the percentage of profit. Had the work to be done over again, the further experience gained would enable much better results to be obtained, with a proportionate increase both in the amount of the proceeds and in the percentage of profit. Where 1,081,263 oysters were lifted, fully 1,750,000, and not improbably 2,000,000, could now be taken in the same time and under similar circumstances.

For the next five months the steamer will be laid up in Colombo Harbour, failing employment on duties other than those of the Pearl Fishery Department. And there is one of great utility and of some urgency. I refer to the utilization of the steamer in her original *role* of fish-trawler. It has already been mentioned that trawling was attempted in 1902 on the Ceylon coast with discouraging results. Were I a capitalist I should, however, be content, armed with my present knowledge of local conditions, to renew the effort. I am confident that worked upon rather different lines and in co-operation with native fish-curers and fish merchants, the enterprise would be a huge success and of far-reaching benefit to the Island.

I submit, therefore, that modern and up-to-date fish-trawling gear be obtained and installed on the "Violet;" that a capable trawling master be obtained from England; and that the steamer be sent to explore the rich fishing grounds which I know to exist off the north-east coast of Ceylon.

This trawling exploration would be conducted during the continuance of the south-west monsoon, when pearl fishery work is necessarily in abeyance. Other Governments, notably that of Cape Colony, have shown the way to local enterprise in the manner I recommend should be followed locally; their work, as I would suggest should also be the case here, was entirely pioneering. In the seas alluded to neither scientists nor fishermen knew the fishing potentialities of the sea bottom save that immediately adjacent to the shore line; banks had to be sought for, and the presence in paying quantities of marketable fish had yet to be demonstrated.

Here in Ceylon the Government is now in a position to carry out such prospecting more efficiently and cheaply than any private individual, being in the possession of a suitable craft and with a Marine Biological Department sufficient to provide the necessary scientific direction.

As the trawling would take place off a sparsely populated coast at a distance from any large distributing centre, it would be preferable to arrange to cure the catches rather than make any attempt to preserve by refrigeration. I recommend that prominent fish-curers should be invited to co-operate; from inquiries I have made I do not anticipate any difficulty would be experienced in coming to a satisfactory arrangement whereby any fish caught by the trawler would be taken over at specified rates by one or more curers and cured by them, thereby relieving the Government of much trouble and risk.

The Sinhalese fish contractors are an enterprising class, endowed with keen business aptitude. I believe that they require only a demonstration of the lucrative character of trawling as a source of supply for their fish-curing yards to induce them to take the matter up on their own account. We have the precedent of other Governments before us, precedents which show that the work suggested lies well within the sphere of duties devolving upon the administration of a progressive Colony.

IV.—CULTURE OF THE BANKS.

It is unnecessary here to do more than give a brief summary of this branch of my work during the past fishery, as a separate and detailed report will be furnished at the close of this year, when, after visiting the banks in November, I shall be in a position to record whether their condition shows any improvement consequent upon the means taken to such end during the past fishery.

The work done falls under three heads:—Transplanting, thinning out, and cultching.

(*a*) *Transplanting.*—For some time after the beginning of the fishery there was no suitable place whereto young oysters might be transplanted; accordingly, the ss. "Violet" was very profitably employed in dredging mature oysters until the time came when the central portion of the South Cheval Paar was fished sufficiently bare by the divers, and thereby rendered fit to accommodate a new generation. From 15th March until the end of the season I caused the "Violet" to dredge over the South Moderagam Paar, where is the greatest profusion of young oysters, and to transfer what were dredged to the South Cheval. Twenty-one days in all were devoted to this work, the result being that a small bed of healthy six months old oysters has been formed at the spot named. The number transplanted amounted to a total of 10,120,000.

Prior to leaving the banks I directed the Government divers to examine the area in question. They reported young oysters apparently numerous; the individuals they brought up were in good health, exhibiting no ill-effects consequent on the transplanting operation. Some had attached to fragments of cultch rubble laid out during the course of the fishery.

(*b*) *Thinning out.*—This operation went on concurrently with transplantation, the abundance of young oysters on the South Moderagam being so inordinate as to constitute, through overcrowding, a grave danger to their own continued prosperity. Transplantation, by entailing a

reduction in the numbers upon the South Moderagam, should react favourably, and if the density of population be found still too great when next the bed be inspected, further transplantation should be resorted to. So great is the present profusion that the numbers taken in the dredges upon the last day appeared as great as on the day transplantation was begun, and indicated no appreciable diminution in the fertility of the bed.

(*c*) *Cultching.*—During the fishery a quantity of rubble obtained from the indurated limestone strata of Kayts, near Jaffna, was laid down, principally upon the sandy portion of the South-Central Cheval, a region which has never yet yielded a pearl fishery. The quantity contracted for was 180 cubes; unfortunately the contractor experienced such difficulties in obtaining vessels to convey the stone to its destination that he was able to deliver less than half the specified quantity although I helped him materially by extending the time limit by a week.

The stone, on the whole, was satisfactory in quality, and likely to prove a durable cultch material. In size the blocks approximated 3½ in. by 3½ in. by 2½ in., but several consignment, contained a proportion of blocks of excessive dimensions, and these I rejected.

The total amount laid down was just under 300 tons. Some 40 tons of the friable semi-calcareous sandstone of Kalpitiya was also used. The greater part was deposited on the South-Central Cheval, some 20 tons on a sandy patch near the centre of the South Cheval, and about the same quantity on the north-east quarter of the South Moderagam Paar, a locality where there is no outcropping rock on the bottom. Several times towards the end of the fishery I received fragments of this cultch from the divers with young oysters attached to the surface.

V.—MISCELLANEOUS.

(*a*) Inspection of Sea Marks.

During the course of the fishery I employed Sundays, the only free time at my command, in an inspection of the beacons and marks which serve to give bearings when searching for and demarcating pearl beds.

Karativu pile beacon, erected over twelve months ago, is in good condition, save for the slackening of two of the wire stays, a matter that will be put right at the first opportunity. No movement whatever of the piles has occurred; the structure retains its perpendicular with exactitude, especially satisfactory considering the severe weather it had to sustain during the past year and the short distance—six feet—the piles are driven into the shifting sand of the shoal. The depth of water remains the same as it was last year. The condition of the ironwork is satisfactory; during their spare time I employed a number of boatmen in scraping it and thereafter in applying two coats of paint. I propose in future to re-paint it twice each year, in November and in March.

Kutiramalai trigonometrical tower was visited in company with the District Engineer of Mannar, who wished me to point out a suitable site for the higher fishery beacon which it is proposed shall be built on Kutiramalai hill. A good path from the shore of Portugal Bay* leads to the old tower. I went provided with the necessary instruments wherewith to take a series of bearings and angles of the various other beacons in sight; to my great disappointment they could not be used, as jungle of 15 feet in height surrounded the base of the tower, while the rude scaffolding giving access to the summit was too rickety and rotten to permit of an ascent. A blank wall of jungle shut out the prospect on all sides.

I selected a site for the new tower about an eighth of a mile due north of the present one. I pointed out to the District Engineer the great advantages for observational purposes from the sea, if lanes be cut in the jungle in certain particular directions from the base of the beacon, say, one in line with the bearing of Karativu pile beacon (approximately N.W. by N.), another in line

* Portugal or Portugai?

with the cocoanut tope of Kurusadai Mondal on Karativu Island, bearing approximately W.S.W. A third might be cut due northwards. Such open lanes would render the beacon more conspicuous on the bearings of greatest importance and thereby increase its usefulness and diminish the risk of error, which hitherto has been so great as to contribute to the occasional loss of a fishery.

I strongly recommend that a permanent stairway be constructed within or around the new tower to give ready access to the summit, that observations may be made therefrom when necessary. Possibly an iron ladder would suffice.

Kallar beacon is in good condition, and one of the most useful marks we have.

Kurusadai Mondal was also visited. The bearing of Kutiramalai tower was taken from the cocoanut tope there; it was found not to coincide with that given on the fishery chart, thereby confirming my belief that there is an error in the construction of the latter, one that calls for the attention of the Survey Department at an early opportunity.

(*b*) Deficient Watering Facilities for the Fishery Steamers.

The lack of suitable facilities for the supply of water to steamers and other vessels employed in work on the pearl banks remains the one great disadvantage pertaining to Marichchukkaddi as the headquarters of the pearl fishery. No arrangement whatever exists to convey water from any of the tanks to the beach; as a consequence vessels are under necessity to proceed to Silavaturai for this purpose, or else a special boat has to be chartered as water tender.

The latter alternative was employed during the recent fishery, but the arrangement proved wholly inadequate to meet requirements, the service being carried out inefficiently by the boatmen employed. The latter were, I understand, Government employés brought from Paumben; lazier and more troublesome men I have seldom met. Not only did they take an inordinate time over each trip, but constant watch had to be maintained lest they supplied a mixture of salt and fresh water. They did supply this abominable mixture on two occasions at least, to my personal knowledge, vouched for by taste and by hydrometer!

Instead of five trips in two weeks, which might easily have been made, there were several occasions when they came but once in the whole week. Fines imposed by the Government Agent appeared to have no effect, and eventually the whole crew deserted. The service was the source of continual trouble and anxiety to me; I was ever in fear lest the work of the "Violet" should be interfered with because of the shortage of water. As it was, the launches could never obtain a supply from the water boat, and were under the necessity to go periodically to Silavaturai to water. As a consequence quite a considerable proportion of their services was frittered away amounting approximately to one-eighth of their time. As their charter cost Rs. 175 per day, the water service by its inefficiency became in consequence an extremely costly one.

The remedy lies in the construction at Marichchukkaddi of a pipe line from one of the tanks to a small reservoir near the shore, where water casks might be filled and rolled thence to the beach. The cost of this would be comparatively little, and fully covered in one fishery by the saving effected by the non-employment of the present water boat service and by the increased efficiency of the steamers engaged in the fishery service.

(*c*) Experiments in Net Preservation.

In January of this year, while living at the fishing station on Dutch Bay spit, I obtained much preliminary knowledge of nets and fishing methods. Among other items I found that the men employ no special preservative for many of the finer nets, especially those of the kind known as "gill-nets"; mangrove cutch (*kadul*) used for the stronger nets cannot be employed because of the objectionable dark brown-red colour which it imparts, and which would scare fish away.

I remembered that the sardine fishers of the French coast, who employ gill-nets in their work, are reported to use nets tinted either blue or green; it occurred to me that the solution which

gives a pale green colour to Willesden canvas, and which is employed not because of the colour, but on account of its preservative qualities, would be very suitable for applying to our local gill-nets, and would have the double advantage of ensuring less visibility and of serving as a useful and much-required preservative. Having knowledge of a method giving a similar colour and rot-proof quality, I explained it to the Sinhalese fish-curer with whom I was staying; he welcomed the suggestion, and promised to make practical experiments upon his own nets if I would obtain the requisite materials and show him exactly how to proceed when I should meet him at Marichchukkaddi during the fishery.

Accordingly, I demonstrated the method one Sunday in March, greatly to the satisfaction of the assembled fishermen, who were especially pleased with the resulting colour. Indeed, I suspect they think more of this attribute than of the preservative quality of the method. I divided the materials I had left among them, and left full instructions written in Sinhalese. They on their part promised to furnish me with particulars of the results obtained. One of the inspection coxswains has also been shown the method, and as he has the control of many fishing nets at Kilakarai and is a most intelligent man I expect a valuable report from him in the course of a few months. I can rely upon him giving the method a fair trial.

(*d*) Biological Notes.

I propose to incorporate the details of biological work carried out on the pearl banks during the fishery in an annual report to be issued at the end of the year, as the publication of results at intervals of twelve months has many advantages over a more frequent issue of observations that must in consequence be frequently incomplete. It will suffice for the present to say that valuable additions were made to the data being accumulated with regard to the rate of growth of oysters on the different banks: hundreds of measurements were made and recorded, together with weights and other particulars. Regular examination and dissection of samples of oysters from the different localities inspected and fished were carried out, and several interesting new facts were made out in regard to the diseases and parasites of the pearl oyster as well as some additional points in anatomy.

(1) *New Parasites of the Pearl Oyster.*

Two new parasites were found, one a small species of leech adhering to the edge of the mantle, the other an immature stage of a new species of Tetrarhynchid worm living in the middle region of the intestine. It is of a smaller size than the young of *Tetrarhynchus unionifactor* common in the same host, differing from the latter in the hooks arming the introverts being conspicuously slender, of a different form, and more numerous. The surface of the body is smooth and entirely free from warting, so characteristic a feature in *Tetrarhynchus unionifactor*.

The life-history of this latter worm was advanced another stage; I found immature individuals present within the second or ascending portion of the intestine in two out of every three pearl oysters examined. All were of the same form and size as those which I have taken from cysts previously. They lie in the intestinal cavity anchored by means of the proboscidial hooks to the intestinal wall; this discovery confirms the opinion expressed a year ago,* that this armature is probably already functional while yet the parasite is lodged within the oyster. The meandering pattern upon the surface of the narrow terminal region of the body was well shown in all, while the immobile bristle-like cilia already signalized as present upon the posterior extremity were clearly seen in some. In others, however, the ciliation appeared absent, a fact which already had been remarked, and which had puzzled me greatly; the explanation is that the large excretory cloaca which exists there, and into which the excretory trunks open, is lined with stiff cilia and is more or less eversible. When partly everted the spinous cilia show as a crown around the posterior extremity in

* Shipley and Hornell, "The Parasites of the Pearl Oyster," p. 85, in Part II. of Professor Herdman's "Report on the Pearl Oyster Fisheries of the Gulf of Manaar," London, 1904.

the manner depicted already in various drawings.* Much attention was also given to the entozoa of fishes: a great number of specimens were collected and drawings made thereof. The report upon the collection will appear in Part IV. of Professor Herdman's "Report on the Pearl Oyster Fisheries of the Gulf of Manaar."

(2) *Function of the Crystalline Style.*

Observations made during dissections of pearl oysters upon the relationship existing between the anterior extremity of the crystalline style and the contents of the stomach have fully satisfied me that Barrois' view of the function of this style—a view hitherto considered doubtful—is undoubtedly the correct one. Thus, specimens examined within a few minutes after being taken from the sea showed, when opened carefully, the anterior extremity of the style surrounded by a sub-globular bolus of food material permeated with viscous matter, which imparted loose adhesion between the food particles. The appearance was as in the annexed figure (fig. 1). The apical part of the style when freed from the adhering food particles is distinctly attenuated (fig. 2), exactly the appearance we should expect to see if a gradual wasting process be in operation. So thoroughly permeated is the bolus mass capping the anterior end of the style with the viscous waste of the latter that I was enabled to remove and preserve the bolus *in situ* on the style in several instances. This positive observation must be considered in conjunction with the fact that out of hundreds of living oysters examined immediately after removal from the beds, and including individuals diseased as well as healthy, not one was found to be without a crystalline style of normal form.

Fig. 1

Fig. 2

These facts go far, I think, to establish the truth of Barrois' theory, that the function of the style is to yield a viscous material for the binding together of food particles within the stomach into a bolus-mass, wherein the sharp points of sponge-spicules, diatoms, and the like may be lost and rendered harmless to the delicate wall of the intestine. Compare the analogous secretion of mucus matter by definite regions of the alimentary canal in the case of certain fishes which feed upon lamelli-branch molluscs, and which thereby injest large quantities of sharp-edged shell fragments.

* *Loc. cit.* pl. II., figs. 19 and 20.

(3) *Breeding-time of Chanks and Octopods.*

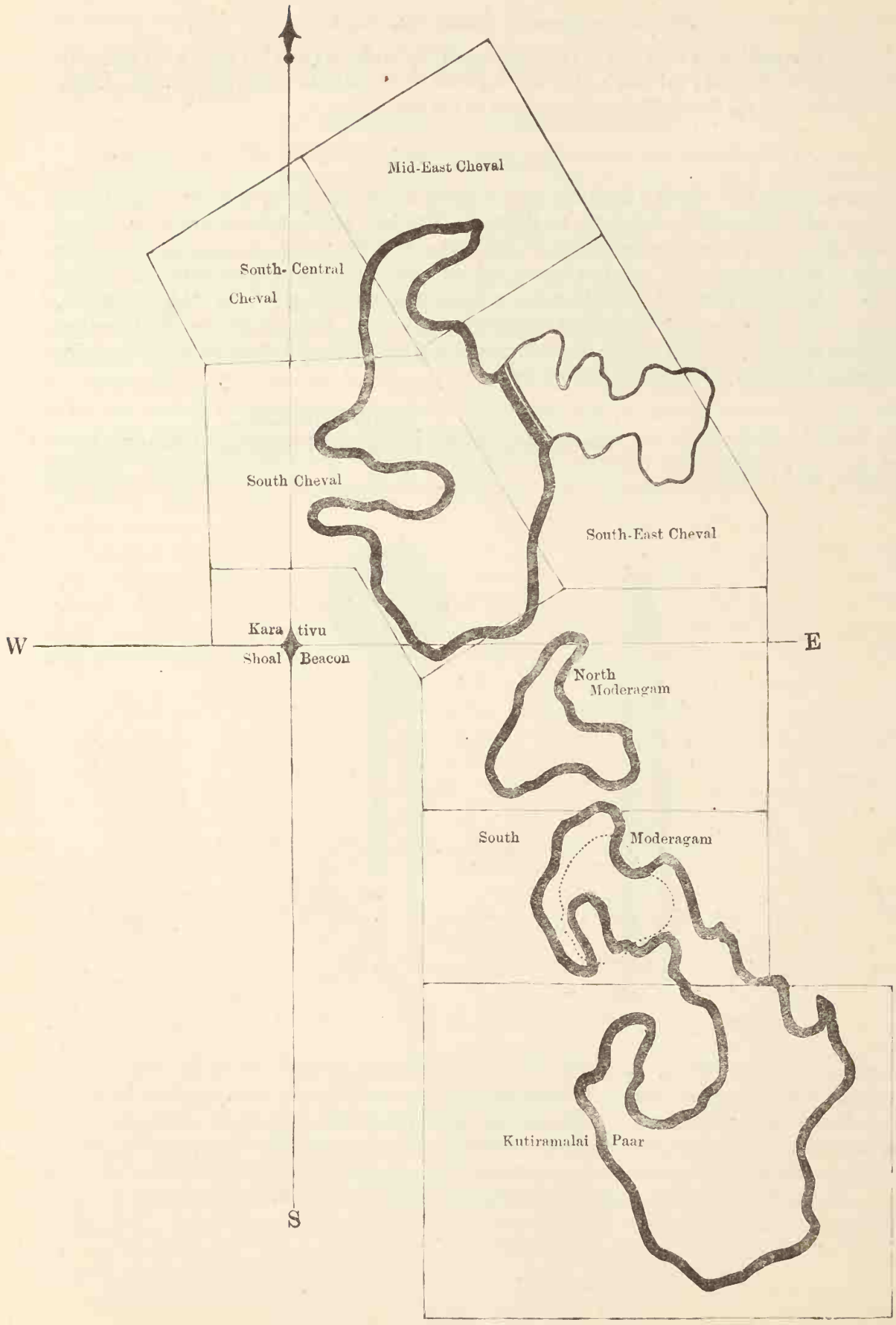
During February large numbers of female Octopod Cephalopods (*Polypus* spp.) were met with carrying strings of embryos; the ram's horn egg-capsules of *Turbinella rapa* (the common chank) were also common on the South Moderagam ground at the same time.

Conclusion.

In concluding this report I must not do so without expressing my very grateful thanks for the courtesy and consideration shown me by the staff ashore, and particularly by Mr. J. P. Lewis, Government Agent and Superintendent of the Fishery, who, with Mrs. Lewis, was ever mindful of the discomforts of life afloat, and did much to lighten the monotony which is inseparable from shipboard conditions. I have also to record my satisfaction with the way in which my clerk, Mr. F. O. Assauw, and the four inspection coxswains performed their respective duties. I should add that the latter had a considerable accession of work during the fishery, as I laid upon them the charge of attending to the proper disposal of cultch rubble over specified areas.

JAMES HORNELL,
Government Marine Biologist and Inspector of Pearl Banks.

Colombo, May 17, 1905.



Sketch Plan of the Fishing Ground of 1905.

Scale :—One nautical mile to the inch.

Explanation.—The thick lines show the area fished in 1905; the thin line the area remaining unfished (the oysters thereon are now 3½ years old); and the dotted line the ground occupied by six months old oysters on the South Moderagam Paar.

No. 4.

REPORTS ON THE MARINE ALGÆ OF CEYLON.

No. I.—ECOLOGICAL AND SYSTEMATIC STUDIES OF THE CEYLON SPECIES OF CAULERPA.

By NILS SVEDELIUS, PH. D.,
Docent in Botany at the University of Uppsala.

I.—INTRODUCTION.

THE investigation of the marine flora of Ceylon, of which this is the first part published, was carried out by myself during the years 1902 and 1903 with the help of a grant from the Regnell Botanical Travelling Scholarship at the University of Uppsala. My stay in the island lasted, with a short interruption, from November, 1902, to August, 1903, and for the greater part of the time I stopped at Galle, on the south coast, which place showed itself to be the most convenient centre for algal studies in Ceylon. Thus, here are to be found close under the ramparts one of the greatest coral reefs in Ceylon, which together with the rocks adjacent offers a rich marine flora living under partly varying external conditions, and at the same time a rich material for studies in various branches of algology. Here, too, I had the great advantage, through the courtesy of the Ceylon Government, of being allowed to carry on my investigations in the newly established Ceylon Marine Laboratory, by which my studies were greatly facilitated. It is with great pleasure that I seize this opportunity of expressing my sincere thanks to Mr. JAMES HORNELL, F.L.S., Marine Biologist to the Ceylon Government and Inspector of Pearl Banks, for the never-failing interest he showed and the great assistance he afforded me in the prosecution of all my algal investigations in Ceylon.

After making myself tolerably familiar with the Ceylon marine flora within a limited district, I extended my knowledge of the algal vegetation by journeys along the coast. So I visited Weligama, Matara, Dondra Head, and Tangalla, in the south ; Gintota, Ambalangoda, Kosgoda, Bentota, Beruwala, Colombo, and Negombo, in the west. The marine vegetation in the north of Ceylon is known to me by studies at and excursions about Jaffna and by visits to Paumben on the Island of Rameswaram. This little island does not belong to Ceylon, but to India ; its situation, however, since it bounds the Gulf of Mannar in the north, justifies it in being included in the Ceylon marine flora district. The vegetation of the east of Ceylon is known to me through a lengthy stay at Trincomalee, on the east coast. Naturally, it was predominantly the littoral flora that was the object of my studies. As far as was possible for me I tried, by dredging, to get to know the sub-littoral vegetation ; but my knowledge of it is unfortunately rather fragmentary, since dredging required a much more complicated apparatus than was at my disposal. Dredging, moreover, is exceedingly difficult to carry out on the open Ceylon coasts with their often difficult bottoms, the more so as the outrigger canoes of the natives are too narrow a craft for such work, which requires broader and more roomy boats. At smaller depths one can conveniently make use of native divers, but the yield from this source is invariably poor. My knowledge of the sub-littoral flora is thus rather fragmentary, and the best material I got from deeper water came from the pearl

banks in the Gulf of Mannar, and for that I am also indebted to Mr. HORNELL, who collected it during his official journeys for the study of pearl oysters.

Important sources for studies in the marine flora of Ceylon are the collections of HARVEY and FERGUSON. W. H. HARVEY stayed in Ceylon from September to December, 1853, and visited Trincomalee, Weligama, and Galle. Of his collections, which are preserved in Trinity College, Dublin, there are duplicates in the collections of the Royal Riksmuseum in Stockholm and in the Algal Herbarium of J. G. AGARDH in Lund. The rich collections of marine algæ made by W. FERGUSON are preserved in the British Museum, but duplicates of them are also in the Herbarium at Peradeniya and in the Herbarium of J. G. AGARDH in Lund. Through the courtesy of Dr. J. C. WILLIS, Director of the Botanic Gardens, Ceylon, the FERGUSON collections in the Peradeniya Herbarium were placed at my disposal at Uppsala, and this considerably assisted me in my studies. I am deeply indebted to Dr. WILLIS for this material help. From the Botanical Museum of Copenhagen and from the Botanical Department of the Royal Riksmuseum in Stockholm I was also allowed to borrow rich collections of Caulerpas, which were kindly lent me as material for comparison, and for which I here beg to thank the Directors of those Institutions, Professor E. WARMING and Professor C. A. M. LINDMAN. Finally, I beg to express my thanks to Professors O. NORDSTEDT, B. JÖNSSON, and S. MURBECK in Lund for their kind assistance during my studies in J. G. AGARDH's valuable Algal Herbarium in the same town.

The extent of my material has forced me to publish my studies in several parts, and if I begin with *Caulerpa* it is because the plants of this genus, interesting from so many different points of view, have hitherto been studied so little in their natural state from an ecological point of view—*i.e.*, their biology. Hence it seemed to me that a real gap in our knowledge of these interesting plants remained to be filled, and that this should be done as soon as possible. It is clear that a study of this nature introduces such difficult questions as the relationship and variation of the species, their geographical distribution, and the like. To try to give an account of the Ceylon Caulerpas from these points of view is the aim of the present essay.

Uppsala, April, 1906.

II.—ON THE MODE OF LIFE OF THE CAULERPAS.

The Relation between Habitat and Organization.—Do Caulerpas show any Examples of Adaptation?

1.—DO ALL CAULERPAS GROW UNDER SIMILAR EXTERNAL CONDITIONS?

Concerning the ecology of the Caulerpas, there are in botanical literature very few, indeed practically no reports. This may be chiefly attributed to the fact that so many of those who have studied the tropical algæ had no opportunity themselves of observing them in nature, but examined them exclusively from material collected by others. Thus, for instance, C. A. AGARDH and J. G. AGARDH, who were the first to give a detailed monographical account of the genus *Caulerpa*, had themselves never collected or even seen any living Caulerpas.

On the other hand also, the algologists who, as HARVEY, had themselves travelled and collected much, only devoted themselves casually to the observation of the habitats of the algæ, of which, as a rule, only short notices were communicated.

Of those who, more recently, have dealt with the Caulerpas monographically, Madame WEBER v. BOSSE and Professor REINKE, only the former had collected her material herself, during travels in the Tropics; but still it is remarkable how entirely her great work, "Monographie des Caulerpes," is lacking in information about the habitats, vertical distribution, &c., of the different species. Hence, too, it is fully explicable that Professor REINKE, in his discussion of the Caulerpas, almost starts *a priori* from the assumption that they all live under practically quite similar circumstances. Thus, in speaking of the problem of the surprising diversity of the organisms ("Ueber Caulerpa," pp. 55, 88), he mentions

precisely the genus *Caulerpa* as an example of a large genus with some 50 species that offer considerable dissimilarities, but which nevertheless live among identical external conditions. The differences between the species are therefore not to be considered as due to adaptations, and in this he finds a support for his theory of exclusively inner causes, "determinants," for the motley multitude of the organisms. As a kind of confirmation of how this conception of the independence of external conditions among the variable Caulerpas prevails in literature, we may mention what Madame WEBER v. BOSSE in a later work ("Etudes sur les Algues de l'Archipel Malaisien," p.128) has uttered in connection with the question about the vegetative propagation of these plants: "La facilité avec laquelle les Caulerpes se multiplient végétativement et *varient sous des influences qui échappent à notre perspicacité** est à mon sens indice de plus qu'une reproduction sexuée ou par spores leur fait défaut."

OLTMANNS however rightly points out (in "Morphologie und Biologie der Algen," I., p. 312) that in this matter we must, for the present, bide our time until the different species have been studied in detail in their natural localities, as well as the external factors that affect them there.

That Caulerpas actually live under very different conditions can already be concluded from various notices in the literature of the group. Thus, for instance, the only European species, *C. prolifera*, which was almost exclusively the form that was the object of detailed investigations and which has therefore been the physiological *Caulerpa par préférence* and has been made the type for the whole genus, is in the Mediterranean apparently a pronounced still-water form, which even if it can occur at the surface (0·5 metre BERTHOLD) yet seems to prefer deeper localities down to a depth of about 15 m.† That it lives under the same conditions in the West Indies follows from COLLINS's note (in "The Algæ of Jamaica," p. 245), that it is not to be found at Jamaica except washed ashore. On the other hand, there are notices in literature about other Caulerpas, which tell us that they live on rocks amongst corals or also in pools; of others, again, that they live in sand and mud, often at no considerable depth (cf. for instance, the above mentioned paper of COLLINS; REINBOLDS; the Marine Algæ in "The Flora of Koh Chang"; A. VICKERS' "Contributions à la Flore algologique des Canaries" and "Liste des Algues marines de la Barbade," &c.).

Therefore, to judge from certain statements in the literature, the Caulerpas do not live under such quite identical external conditions as is commonly supposed. And that the Ceylon species of *Caulerpa* occur to some extent under greatly different external conditions, and that this, in its turn corresponds with evident differences in organization, I hope to show in the following pages.

In examining whether, among a group of plants, the different forms or species really show examples of adaptations to their surroundings, or to employ a term first used by DETTO, they are ecologisms ("Okologismen"), we can proceed in different ways. Since, just as in the following case, direct experiments were out of the question, the comparative method is the only one which analytic ecology can adopt. We can, then, compare either widely different species, *i.e.*, such as have different characters of organization ("Organisations-Merkmale" to use NÄGELI v. WETTSTEIN'S expression), but which still live amid similar surroundings, in order to examine whether, besides these characters, others of similar kind (*i.e.* adaptations to the similar surroundings) occur; or, following DETTO, examine whether they may be examples of ecological convergence (DETTO, *loc. cit.*, p. 146). But we can also go to work in another way; we may compare one species, which occurs very plentifully in one district in many forms and amid different surroundings, in order to study the changes it undergoes in the different situations and endeavour to find out whether these may be considered as adaptations to environment.

Of the some 20 species of *Caulerpa* that I found in Ceylon, some are very rare and to be met with in only few specimens; others, it is true, have very limited distribution, but show abundant local occurrence; some, finally, are very widely distributed, and occur in plentiful closely related forms which are hard to distinguish. To the very rare species which are only found in scanty specimens

* Italicized by the author of the present paper.

† FALKENBERG mentions *C. prolifera* in the Gulf of Naples at a depth of from 2-15m. Cf. also A. VICKERS "Contribution à la Flore algologique es Canaries," p. 30.

belong, for instance, *C. scalpelliformis*, *Freycinetii*, *cupressoides*, *Fergusonii*. In abundant individual occurrence, but with very limited distribution, we have *C. verticillata* and *lætevirens*. Lastly, to the commonest and most widely distributed belong *C. clavifera*, *uvifera*, *peltata*, *imbricata*, and others; in a word, all those species belonging to the very critical *racemosa group*, according to WEBER v. BOSSE's definition, a variable group very difficult to define.

If we compare the different situations in which the Ceylon species of *Caulerpa* grow from the point of view of the character of the substratum, we shall find in a preponderating number of cases that it consists of firm rocky or coral ground. But very commonly, too, *Caulerpa* grows on soft bottom, in sand or coarse gravel formed by decomposition products of the reefs, remains of corals and lithothamnia, or again in soft mud carried out to sea by rivers and streams.

2.—DIFFERENT ECOLOGICAL TYPES AS DISTINGUISHED BY VARYING DEVELOPMENTS OF THEIR ROOT-SYSTEM.

(A.) *C. verticillata type.*

Do the Caulerpas show any differences in their organization and mode of growth upon the different bottoms ?

Let us first examine *C. verticillata* (fig. 1), which I observed at the mouth of a river on rocks partially and at times, during the south-west monsoon, entirely covered by sand and mud carried out to sea, as was the case at Galle. The tufts grow in very thick masses which all arise from more or less deep growing axes, now horizontally (fig. 1*a*), now obliquely growing upward (fig. 1*b*), and which higher up form side axes which grow out horizontally. Evidently this mode of growth is very favourable to a *Caulerpa* growing in localities exposed to the danger of being covered by sand, and this whole mode of growth is quite analogous with that of the dune grasses or certain bog mosses, which are characterized by a continuous succession of dyings-off in the basal parts in proportion as they sink deeper down. This comparison, first suggested by REINKE, is really very striking, and is strengthened by the fact that down in the mud we find remains of verticil branches which have been killed and buried in the sand.

Through the stimulus to upward growth which the over-sanding exercises, this plant can always keep its assimilation branches in the light where they stick up out of the mud and wave to and fro in the swell. Thus *Caulerpa verticillata* seems to show, in its system of shoots, an example of an organization adapted to the surroundings in which it lives. The information about the situations wherein this plant lives in other countries is very scanty. Both JOHS. SCHMIDT ("Flora of Koh Chang," IV., p. 104) and COLLINS ("Algæ of Jamaica," p. 245) only mention that it grows on coral reefs without any further specification.

Mlle. VICKERS ("Liste des Algues marines de la Barbade," p. 57) only says, "Flaques, abritées, à basse mer." Remarkable, on the other hand, is COLLINS's note on the *f. charoides*, which is closely related to the main species, *C. verticillata*. He says of it (*loc. cit.*, p. 245) that it grows "in soft mud near Mangrove swamp," consequently in localities to some extent similar to those where *C. verticillata* occurs at Galle. But if, in other respects, there can be discovered any analogies in the formation of the shoots, cannot of course be determined as far as this form is concerned, any more than is the case with the other related Caulerpas belonging to the *Vaucherioideæ*- and the *Charoideæ*-group, all of which are distinguished by finer and weaker shoot systems than are to be found in other Caulerpas. In *C. verticillata*, therefore, we have found a type of *Caulerpa* which grows in soft, muddy bottom, where the danger of oversanding is present, and I have not seen another *Caulerpa*-species in Ceylon belonging to the same biological group, nor do any other Caulerpas occur together with *C. verticillata* in the localities where it grows.

(B.) *Sand Caulerpas.*

Another type of the Caulerpas that grow in a movable substratum is represented by such species as *C. Freycinetii*, *cupressoides*, *Lessonii*, and *Fergusonii*. The figure of *C. Lessonii* (fig. 11) gives us a good idea of this rhizome type, which seems to be rather common among the Caulerpas and of which

Reinke has figured several, as, for instance, *C. flagelliformis* (Reinke, *loc. cit.*, fig. 10), *prolifera* (fig. 11), *Freycinetii* (fig. 38), *paspaloides* (fig. 52), and others. The characteristic of these species is that the rhizome is rather coarse, sparsely branched, grows more or less deep in the sand, out of which only the assimilation branches stick up in long rows, with small or great intervals between them. Of *C. Freycinetii* we consequently only see as it were ball-shaped bundles of assimilation branches entangled together. In Ceylon this type of *Caulerpa* is only met with in the north, around Adam's Bridge and the islands about Jaffna, where the shore is always sandy. On the coral reefs and rocky shores of the south-west, this type is scarcely to be met with. To judge from certain indications, this *Caulerpa* type consists chiefly of still-water forms, which therefore often prefer somewhat deeply situated habitats. Thus *C. Lessonii* has only been observed on the pearl banks at a depth of several metres. *C. Fergusonii*, too, does not belong to the upper littoral zone, either. *C. Freycinetii* has been collected by me in the upper littoral zone, it is true, but since it only appears there occasionally we are tempted to assume that its main distribution lies deeper down. That this is not a mere chance guess, and that it has some justification is supported by the fact that Johs. Schmidt collected *C. Freycinetii* in the Gulf of Siam at no depth less than 2 metres, and as for *C. cupressoides* we are told that it occurs in such localities as lagoons (Börgesen), which points to its being a still-water form.

Besides being distinguished by its mode of growth—*i.e.*, half hidden in the sand—this type is distinguished also by its root branchlets being very long and especially very closely and finely branched, and between the fine root branches the particles of sand are pressed so tight that large lumps accompany the plant when it is pulled up from the bottom. Reinke has described this type and given several illustrations of it in his paper (*loc. cit.* figs. 20, 38, 42, 52, 73). As ecological adaptations to the conditions of the life of these plants in the sand, we may consider their long-creeping rhizome axis and especially the development of their root system. Such repeated branching in a great number of fine filaments which fasten themselves firmly to the grains of sand may be taken as an excellent anchoring apparatus for a plant living on a sandy bottom. In this type there is no organization of the shoots to neutralize the danger of being oversanded—a danger which is not to be feared in such places as those where this plant is to be found. Approximating to this type are such species as *C. crassifolia*, *C. dichotoma* (fig. 23), *C. uvifera* (fig. 15), and others, which if not invariably, at least most generally, have a mode of growth analogous with that of the sand Caulerpas just described.

(C.) *Rock and Coral Caulerpas.*

The most numerous Caulerpas belong to a group which grows preferably on stones, corals, and in general, fixed substrata. But here the conditions may be of most dissimilar nature, owing to the different degrees of exposure to the swell, to the other local conditions affecting vegetation, to the presence of Actinians and living corals, and so forth.

(*a*) *C. lætevirens type.*

Among these rock Caulerpas, *C. lætevirens f. laxa* (fig. 19) takes a unique position inasmuch as this species grows by preference in exposed localities, where it constitutes the sole vegetation (forming a special *C. lætevirens* association), and covers large areas, as at Galle, on the boulders north of Victoria Park.

C. lætevirens f. laxa there forms a typical algal association of a kind that has been described from northern seas, and that has been called "böljslagsformationer" by Gran ("wave-beat formations" is the literal rendering), in "Kristianiafjordens algflora," p. 9. Such formations or associations are, for instance, the *Nemalion* formation of the west coast of Sweden (Kjellman, "Algenreg.und Algenformationen," p.11), the *Bangia-Urospora* association of the Faeröese coasts (Börgesen, "The Algæ-Vegetation of the Faeröese coasts," p. 719) and the *Gobia-Dictyosiphon* formation from the Baltic (Svedelius, "Ostersjöns Hafsalgflora," p. 29). What characterises all these formations* is that they are very exposed to the swell and hence are in continual movement, waving to and fro, covered one moment, free the next, in never-ceasing alternation.

* This use of the term "formation" is analogous with the sense in which it is employed in Geology.—Ed.

Such algæ must, of course, be firmly fixed to their substratum. Whereas the European forms of this type are characterized by smaller or greater adhesive discs, *C. lætevirens* has quite a different method of fastening to the rock. In this we find, as in the other Caulerpas, a creeping rhizome, but here much more developed than in the species in general. The assimilation axes, on the other hand, are few and placed at comparatively long intervals, and hence the root system, since it develops numerous fine root branches that fasten themselves to the smallest crevices, corners, or irregularities in the rock, becomes in these plants, in proportion to the assimilation system, much greater than in the other *Caulerpa* species. To this must be added—and this seems to me by no means the least characteristic feature of this species—that the assimilation branchlets or pinnules have a strong tendency to grow out into root-forming branches (fig. 19), whereby the whole plant is still more firmly fastened to the rock. That assimilating shoot branches change their character, become procumbent and take root, is, as Weber v. Bosse has pointed out ("Monographie des Caulerpes," p. 249), not a rare phenomenon. I have given a picture of such a case in *C. Fergusonii* (fig. 51 a, b). But in *C. lætevirens* it is the branchlets or pinnules (fig. 19, f–i) that grow out into haptera-like rhizomes, and this has become very common in this particular species. As for the shoot system in general, we refer to the description of this species in the special section of the present work. That all this organization is highly advantageous to a species exposed to strong swells, and to the resultant danger of coming loose, is evident; and *C. lætevirens f. laxa* must therefore indisputably be considered as an ecological adaptation to such surroundings.

Very remarkable is the changed appearance this plant assumes (figs. 21 and 22) when it grows in somewhat deeper localities not so directly exposed to swells. I have called this biological form *f. cæspitosa*. It becomes tufted owing to the assimilation branches growing very close together. They are moreover shorter, coarser, and especially more rigid (fig. 22), so that they cannot wave to and fro in the water. To this contributes also the fact that this *f. cæspitosa* grows squeezed between other tufted algæ. Its rhizome and root system are normally developed, not stronger than in the other Caulerpas, and the branchlets, moreover, show no tendency to grow out into root-taking branches. The small, short assimilation-branches are not so pliant in *f. cæspitosa* as in *f. laxa*, but more rigid. They are often clavately swollen at the tops, or sometimes flattened. In the last-named case torsion often occurs (fig. 22, b, c), so that the flattened sides are turned up to the light. It is evident that both the clavate form and the torsions of the branchlets produce the same effect, viz., as great a number of chloroplasts as possible are exposed to the light falling from above. It is interesting that this happens only in *f. cæspitosa*, the rigid form with the stiffer branches. The *f. laxa*, on the other hand, in which the branches wave to and fro, thereby receiving the light from every side, shows no such peculiarities in the organization and position of the branchlets. In this, too, both these forms show differences in their organization that are to be looked upon as ecological adaptations.

We shall reach a similar conclusion if we compare *C. lætevirens* with *C. dichotoma* (figs. 23, 24). As will be pointed out in the more detailed description of this species, it is closely allied to *C. lætevirens*, from which it differs chiefly in its broad flattened dichotomous assimilation branches, commonly arranged in two rows along the main axis. This organization means a considerable increase in the assimilating surface, but at the same time it entails a number of disadvantages to an alga exposed to strong swells. *C. dichotoma* is consequently not found in the upper littoral region in places which are so characteristic for *C. lætevirens*, but at Weligama it grows at a depth of about 2 metres on sand. The horizontal axis and the root system also corresponds far more in coarseness with the sand Caulerpas than with the fine creeping axis of *C. lætevirens*.

Also in *C. dichotoma* the easy transition from assimilation-branches to haptera is entirely lacking, the reverse of the case in *C. lætevirens*, wherein this is so closely connected with its mode of growth. Hence, we see that the characters of these related species are undoubtedly in complete correspondence with their mode of growth and with the closely connected surroundings.

It is remarkable that *C. lætevirens* seems to live under similar conditions on the coast of Western Australia as in Ceylon. Thus HARVEY says (in "Phycologia Australica," I., Pl. XXX.) about *C. cylindracea*, SOND. (= *C. lætevirens f. cylindracea* (SOND) WEBER v. BOSSE) : "This plant is excessively common on all the reefs at Rottnest Island, growing in shallow, exposed tidepools, as well as in sheltered spots below low-water mark, and it varies much in luxuriance according to the locality."

From these remarks it follows in any case that *C. lætevirens* in Australia forms a special association with its environment, especially in exposed localities, but that it also grows in deeper and more sheltered places. And, just as at Galle, the different forms also seem to be dependent on the different localities. In what way these make their influence felt HARVEY does not mention. He only speaks in a few words of the variation of *C. cylindracea* "in luxuriance according to the locality."

(*b*) *The remaining rock and coral Caulerpas.*

If, now, *C. lætevirens f. laxa* is a pronounced, even though rare, example of a rock *Caulerpa* growing in strongly exposed localities where no other alga happens to occur, on the other hand we find a preponderant number of other species also growing on rocks, but in more sheltered places, where they occur in company with other algæ, and especially with living corals and small Actinians.* I have frequently observed that amongst living corals and Actinians the Caulerpas must be considered as a characteristic occurrence. With their long rhizomes they creep among the Actinians, and only the assimilation branches are visible where they shoot up between the animal colonies. Such is the case with several forms of *C. clavifera*, *nummularia*, &c. Especially noticeable is *C. longistipitata* (fig. 45) with its long rhizomes creeping on rocks and among other algæ, even if it does not occur on such strongly exposed localities as *C. lætevirens f. laxa*. All these have a root system without the very fine branching present in the sand Caulerpas ; the root-branches, on the contrary, are fewer but coarser, and often as if flattened at the top where they are fastened to the stones. But that there is no hard and fast difference between such a root system and the one that occurs in the sand Caulerpas is best proved by the fact that the same species has now the one, and now the other, depending on the substratum. REINKE has already pointed this out (*loc. cit.*, p. 58).

3.—DIFFERENT ECOLOGICAL TYPES AS DISTINGUISHED BY THE VARYING DEVELOPMENT OF THEIR ASSIMILATION SYSTEM.

If, then, as we have already seen, there is a great difference in the root systems or adhesive organs in general, at least within certain *Caulerpa* groups, the difference is much greater in the assimilation branches and the shoot system. It is really with reference to this difference that REINKE ("Ueber Caulerpa," p. 67) seems to have been led to the opinion that the genus *Caulerpa* offers a special point of interest, because it shows that even under similar external conditions and with essentially similar inner organization, the external form can yet be variable : "Alle Caulerpen sind dem Lichtleben in Wasser angepasst : jede Art ist ein Spezialfall dieser Anpasung, und alle sind verschieden geformt. *Diese Verschiedenheit beruht aber nicht auf besondere Anpassungscharakteren.*† Die Assimilationsarbeit lässt sich bewerkstelligen eben so gut mit gleichartigen feinen Fäden der *C. fastigiata*, wie mit den breiten ungetheilten Blättern der *C. prolifera*, den grossen fiederspaltigen Blättern der *C. taxifolia* und den kleinen einfachen Blättern der *C. racemosa* und *Lycopodium*" . . . . and again we read : "Wer es liebt, auf die Unterscheidung von morphologischen und Anpassungsmerkmalen Werth zu legen, der wird daher die Speciescharaktere von *Caulerpa* sowhol zu den ersteren wie zu den letzteren rechnen müssen." But none the less REINKE has a feeling of the possibility that the Caulerpas may be, for all that, more or less adapted in their main functions to their surroundings, and he adduces as an example how a fine-leafed species—as *C. hypnoides* — has greater possibilities of profiting by and making the fullest use of the light in every situation than for instance a *C. taxifolia* or *C. prolifera*, and these advantages show themselves chiefly in moving water.

* These are chiefly Zoanthids.—ED.

† Italicised by the present author.

If we examine the assimilation system in the Ceylon Caulerpas, we shall find several different types and variations. They may be roughly divided into two groups, viz., such as have the assimilation system very strongly branched (always a system of short shoots, pinnules), and such as in their assimilation organs have a measure of correspondence with, or at least some outward resemblance to, the leaves of the higher plants. To the latter group belong such forms as *C. scalpelliformis* (fig. 2), *crassifolia*, *taxifolia* (figs. 4, 5), &c. ; to the former such as *verticillata* (fig. 1), *clavifera* (fig. 13), *uvifera* (fig. 15), *lætevirens* (fig. 19), &c. But a division of this kind is of course incomplete and vague. For it could also be expressed in this way : the one group (the leafy one) is characterized by its assimilation branches being bilateral, the other by its axes being radial. But here it is to be observed that only the main axes are radial, the lateral axes or the short shoots may afterwards assume the most variable shapes. They, too, can be radial, *i. e.*, cylindrical as in *C. lætervirens f. laxa*, cylindrical with spherical point as in *C. loncistipitata* (fig. 45), *crassicaulis* (fig. 47), *clavifera*, *uvifera*, &c.; finally, disciformly flattened, as in *C. nummularia* (figs. 35, 36), *imbricata* (fig. 30), and others. The questions now arise whether in these various leaf and shoot forms we can see any adaptations to their different surroundings ; whether one can be considered in any way more perfect than another, or whether they are all equally good for the purpose, and whether really the great variability is only to be ascribed to formative energy in the plant that escapes our direct observation. We will deal with these in that order.

(A).—*The bilateral leaf-like Caulerpas.*

It seems to me indisputable that the leaf-like flat Caulerpas are derived from radial forms as being the more primitive ones ; that they are very closely related is shown already by such a species as *C. flagelliformis*, of which there are both radial and flattened forms, very similar to one another and often passing over from the one to the other. Such a fine leaf-like species as *C. prolifera* can even be transformed, as KLEMM has shown, into the cylindrical form, exactly in the same manner as several species of *Opuntia*.

A comparative examination of the assimilation axis of the bilateral species shows moreover that the bilateral axes are often radial at the base, and there form branchlets round the axis. This by no means rare case is illustrated in this work by *C. Lessonii* (fig. 11, the branches to the left of the picture), by *C. taxifolia f. tristichophylla* (fig. 5), and also by *C. dichotoma* (fig. 24, *a*) where some branches at the base show weak indications of radial arrangement. It is evident that by the lateral arrangement a surface increase has been gained, the advantage of which for the work of assimilation is self-evident. So far, as great an increase of surface as possible were desirable, provided no disadvantage were involved. But such is undoubtedly present; the large flattened leaf-like organ, without any special mechanical elements or tissues, runs a great danger of splitting if exposed to too violent a strain, in the form of ground-swell or the like. That *Caulerpa prolifera* is actually very susceptible to this, and cannot withstand a too turbulent sea follows very clearly from JANSE's notes ("Bewegun. d. Protoplasma von *Caulerpa prolifera*," p. 166) on broken Caulerpas in the Gulf of Naples after very stormy weather, which has stirred up even the quiet depths where *C. prolifera* lives. It is evident, therefore, that if such broad-leafed forms are to have any chance of living it must be in sheltered places, and, of course, especially at considerable depths that are not disturbed by heavy seas. In this respect how does the matter stand with the other leaf-like Caulerpas ? It has already been pointed out above that *C. prolifera* is by preference a deep water form, both in the Mediterranean and in the West Indies. The same may be asserted of *C. scalpelliformis*. In the littoral zone I only found it once, at Paumben, and for the rest it is wanting in the littoral zone of Ceylon. As, however, it has been noted from the pearl banks in the Gulf of Mannar (E. S. BARTON, "List of Marine Algæ collected . . . . at Ceylon," p. 165), and has moreover been obtained by JOHS. SCHMIDT at as great a depth as 15 metres and more in the Gulf of Siam ("Koh Chang," IV., p. 104), and as it is mentioned by HARVEY ("Phycologia Australica," I., Pl.17) as growing "a few feet below the low-water mark," we may consider ourselves justified in not counting *C. scalpelliformis* among the typical algæ belonging to the upper littoral zone, but as a Caulerpa which prefers somewhat deeper regions.

The same may be said of *C. crassifolia*. I only found it once in the littoral zone of Ceylon, and then in its deeper parts at a depth of about 2 m. On the other hand it does not seem to be rare on the pearlbanks in the Gulf of Mannar. No detailed information as to locality is present from other places. It is highly probable, by reason of its appearance in Ceylon, that this species also belongs to those which prefer somewhat deeper regions. On the other hand *C. crassifolia* is, even if evidently bilateral and provided with rather broad and flat main axes, so lobed that the danger of splitting is not really serious in this species, even if it grows in exposed places in the upper littoral zone. What is true of *C. crassifolia* is true also of *C. taxifolia* (figs. 4, 5) and its different forms. It avoids exposed localities when it grows in the upper littoral zone, where it is to be met with in pools. On the other hand, it is plentiful on the pearl banks in deeper water. COLLINS only knows this alga from Jamaica as "washed ashore." The deep-water form, *f.asplenioides* (fig. 4), has somewhat broader but shorter pinnules, directed straight outward, the surface form smaller but longer, and sickle formed branches bent upwards. Remarkable is HARVEY'S note on this species ('Phycologia australica,' III., Pl. 178): "There is fully as much difference among my Friendly Island specimens, between those collected in the quiet waters of the lagoon and those from the outer reef, as I find in those from opposite hemispheres."

HARVEY thus remarks in this species variations according to different situations, but without characterizing the nature of the changes.

An examination of the occurrence of *the larger bilateral Caulerpa* forms both in Ceylon and on other coasts, where anything is known of them, consequently shows that in any case they have *not* their main distribution in the littoral zone—even if isolated specimens occur there—but that this *must be located in deeper and quieter regions.*

(B).—*The radial Caulerpas—The Analogy between the C. clavifera-uvifera type and the C. nummularia-peltata type.*

Where do we find, on the other hand, the Caulerpas which have radial structure of their assimilation system in the form of short-branches ?

Of the *Caulerpa* species of Ceylon, besides the *C. verticillata* and *lætevirens* which have already been dealt with, we have in this group *C. longistipitata*, *sedoides*, *clavifera*, *uvifera*, *peltata*, *nummularia*, *parvula*, *imbricata*, and *Chemnitzia*. It should be observed at once that all these species occur in the littoral region, and several of them belong to the commonest algæ in the upper littoral region. Some species with wide distribution are also to be met with deeper down, and these show very instructive and interesting changes of form. More of this later on. A few species, as *C. longistipitata* and *C. sedoides*, have only been found in relatively very few places; but as JOHS. SCHMIDT ("Flora of Koh Chang," IV., p. 105) also mentions them only from the littoral region, they seem most probably to be at home in this region.

Under what conditions do these forms live, and can we see any adaptations to their surroundings in their organization ?

Let us first examine *C. clavifera* (fig. 13). In the special part the characteristic mode of growth of this species is dealt with. The form which is pictured in fig. 13 is a pronounced surface form, which at low water is often only laved by the waves. Its characteristic is its extended—almost flattened—mode of growth, which depends on the vertical axes being so short and having only a small number of side branchlets. When, at the same time, the root system and the horizontal axes are strongly developed, the whole plant is firmly fixed to the rock, while the small short vertical axis offers few points of attack to the swell. It is to be noted that as a rule no Caulerpas at all—with the possible exception of *lætevirens*—are ever met with in the littoral region in really strongly exposed localities, but *C. clavifera* can sometimes grow in places which, even if the sea there cannot be described as violent, are yet exposed to wear and tear of a kind. In such places we often come across *C. clavifera* and others with similar construction, as *C. nummularia* and others. It is rather remarkable that these Caulerpas are so often to be found among small living corals and small colony-forming Actinians. The horizontal axes creep amongst the Actinians

and fasten on to them. *C. clavifera* then often gets somewhat longer vertical axes, and the whole plant assumes an appearance more closely resembling TURNER's *Fucus clavifer*, Pl. 57, vol. I., and WEBER v. BOSSE's, fig. 4, Pl. XXXIII.

If it grows directly on the rock and more isolated, it appears as in fig. 13. That for such a pronounced littoral alga, which grows squeezed in between Actinians and corals, such a mode of growth offers certain advantages, seems evident to me. Partly because, as mentioned above, the surface exposed to the waves is relatively small compared with the well-developed adhesive system, partly because the exposure of the assimilation system—and this, I think, is worthy of special note—becomes under such circumstances the most favourable, since it is practically spread out in one level and thereby as many branchlets as possible are exposed to the light. That, for instance, the taller vertical axis with pronounced uviform shape, as *C. uvifera* (fig. 15), cannot be a suitable form amongst corals will easily be understood, for if these vertical axes are squeezed in between equally high corals, only the uppermost branchlets, that is the points alone, can be exposed. Therefore short axes with few side branchlets must be considered as especially suitable shapes for such habitats. The reduction in the assimilation system that results from the diminished number of branchlets is compensated by their being larger and coarser. It is also in such localities that we meet with forms with very large ball-shaped branchlets, KÜTZING's *Chauvinia macrophysa*.

These observations of mine concerning the occurrence and mode of growth of *C. clavifera* in Ceylon, correspond with Madame WEBER v. BOSSE's note on *C. clavifera f. macrophysa* ("Monographie des Caulerpes," p.362) where we read : "J'ai recueilli la plante sur des recifs de corail : la fronde de la *v. clavifera* était enclavée entre des morceaux de corail, les ramules s'étaient par conséquent tournés du côté de la lumière, s'étaient rapprochés du côté frontal de la fronde et en meme temps agrandis." This seems to indicate that the assimilation branches were all as in a level at the same time as they were enlarged.

I have therefore come to the conclusion, as a result both of my own observations and of such notices in botanical literature as the above, that *C. clavifera* may be characterized as the coral reef Caulerpa *par préférence*.

The changes *C. clavifera* undergoes when it grows deeper down can in general be characterized by the vertical axis, as well as the cylindrical parts of the assimilation branchlets, being lengthened. The *f. remota* (fig. 14), described by myself, is such a pronounced form from a deep pool. Its vertical axes are very lengthy, are not recumbent, nor root-taking. Between this and the surface form intermediate forms can be found. The *f. remota* as a form living in deep pools is never exposed to the tearing influence of the swell to the same extent as the main form. Its root system is relatively weaker, but the assimilation branchlets are longer, slenderer, and more pliable, so that when they wave to and fro they also can derive every benefit from the light.

That these various forms arise directly through the influence of light, so that, for instance, obscuration favours the lengthening of the axes, while bright or intense light causes shortening of the axis system, seems very probable. But this can only be determined by direct experiments. A comparative examination shows, in any case, that the one type is almost exclusively at home in the upper littoral region, the other in somewhat deeper localities. For analytical ecology, however, it is sufficient to state that both kinds of forms in this organization have certain advantages suitable to the different surroundings amid which they live, and can therefore with good cause be considered as adaptations or ecologisms.

This *C. clavifera* organization shows itself still more closely an ecological adaptation if we compare it with *C. uvifera*. In the special section I have dealt in more detail with the differences which exist in Ceylon between these two species. In this place I may call special attention to the fact that *C. uvifera* will be looked for in vain on the coral reefs of the south-west of Ceylon. It is this species however that seems to be the commonest in the north. At the present time I do not venture to decide whether this different distribution of the two forms is to be exclusively attributed to the different nature of the shores ; viz., that on the south-west and south coasts there occur only cliffs and rocks, which are favourable

to the growth of *clavifera*, whereas such formations are rare in the north. There the shores are more sandy, with very scanty vegetation in the upper parts of the littoral region, and with algal life beginning only a little further down. That *C. uvifera* is closely allied to the sand Caulerpas, I have already pointed out. Though it is chiefly the rhizomes and the root system in which this appears, yet even the assimilation axes point to its being predominantly a deep form. For the assimilation axes are much longer than in *C. clavifera*, and especially very thickly covered with branchlets, which show a firm cluster-shaped formation (fig. 15). That such an organization is very unsuited to exist amongst corals and Actinians has already been pointed out above ; it would be equally unsuited to strongly exposed localities. Deeper down in sandy bottom, however, it has a more suitable habitat, and the long vertical axes wave to and fro in the currents so that the whole axis gets exposed to the light from every side. As Johs. Schmidt (*loc. cit.*, IV., p. 105) also only found *uvifera* at a depth of from "1-2 fathoms water (coral sand)," the opinion I formed about this plant in Ceylon is strengthened : the opinion, namely, that it is a sand Caulerpa from somewhat deeper regions.

With respect to the variations of *C. uvifera* and their ecology I need not take up much space, since I have only collected *f. planiuscula* myself. It differs only in that its upper branches show a tendency to flattening out (fig. 16), while the vertical axes at the base have rather few side branchlets. This change seems to be favourable to the reception of light coming directly from above, but about the special habitats of this plant my notes unfortunately do not afford me any help. It occurs only in the north of Ceylon, with about the same distribution as the main species.

C. longistipitata (fig. 45) and *C. sedoides f. crassicaulis* (fig. 47) have a similar organization to that of *C. uvifera*. As far as *C. sedoides* is concerned, at least, the resemblance seems to apply also to its mode of growth, for at Weligama it grew inside the reef at a depth at low-water of about 2 metres together with *C. taxifolia* and *sertularioides*, anyhow not in the upper exposed part of the littoral region. At Matara it occurred in rock pools. It also seems capable of variation in the length of its shoot axis, some branches being very short (fig. 47), analogous with those in *C. clavifera*.

C. longistipitata, on the other hand, seems to show some analogies with *C. lætevirens* in its lengthy root system that creeps along the stones, and its long, slender, and weak assimilation branches. It occurs at Paumben in the upper littoral region, but not in any exposed places. Seeing that I only observed it in that place, I will not venture to express any opinion as to where this form is really at home, but Johs. Schmidt (*loc. cit.*, IV., p. 105) also informs us that he only found it in the littoral region.

Of the remaining species that occur in the littoral region, *C. peltata*, *nummularia*, *parvula*, *imbricata*, and also *Chemnitzia* may be considered as a very uniform and closely related group, distinguished by all their short branchlets being more or less pronouncedly disciformly flattened.

Of these species *C. nummularia* (figs. 35, 36) occurs in about the same localities as *C. clavifera*, *i.e.*, in the upper littoral region, not rarely together with corals. The organization of the shoots is also quite analogous with that of *C. clavifera*. The branches are all recumbent, root-taking, and creep among corals and on stones. These branches are dorsi-ventral and form disciform assimilation branchlets on the upper side only. The whole plant resembles a matty tuft (fig. 36) with the assimilation system in one level. Thus we here find an organization quite analogous with the one we have already described in *C. clavifera* (fig. 13), and which is characterized by the relatively strongly developed root system in comparison with the shoot system, and by the shortening of the shoot axis, whereby the assimilation system is flattened out so that it receives the whole light vertically from above. *C. clavifera* and *C. nummularia* are both pronounced light algæ from the upper littoral region, growing in localities with frequent changes of water and often somewhat exposed to the swell. These analogies in the outward conditions of life correspond to pronounced resemblances in mode of growth. Therefore, too, these forms might with reason be characterized as ecological adaptations ; they are, as Detto says ("The orieder direkten Anpassung," p. 146) *examples of ecological convergence*.

What is true of *C. nummularia* is also true of *C. parvula* (fig. 43), which in its mode of growth and occurrence is quite analogous with *C. nummularia*.

In the same way as in the series with the ball-shaped branchlets, *C. clavifera* is a surface form, and the more long-branched *uvifera* is a deep form ; similarly, in the series with disciform assimilation branchlets, the surface form *C. nummularia* (fig. 36) has an analogous form in the relatively deep form *peltata* (figs. 31, 32, 33). The changes in form in the *nummularia-peltata* series are also quite analogous with those in the *clavifera-uvifera* series. *C. peltata* has long vertical branches with the side branchlets placed all round and their flattened assimilation discs obliquely directed upwards (figs. 31, 32, 33), whereas *C. nummularia* has recumbent axes with assimilation discs on the upper side only (fig. 35). It is evident that with this position the exposure of these branchlets to the light is the most favourable one for vertical axes when they have branchlets all round them, for horizontal ones when they have them dorsiventrally developed. That some transition forms with both radial and dorsiventral axes can be found (fig. 32) will be pointed out by me in the description of the different species.

Just as *uvifera* was predominantly a deep form, so too this *C. peltata* is only to be met with deeper down in rock pools and other places not too strongly exposed.

What applies to the different types of the *clavifera-uvifera* series as far as their advantages and disadvantages are concerned, applies also, of course, to the *nummularia-peltata* series. *Thus we see that between C. peltata* and *C. uvifera there is a similar ecological convergency to that between C. nummularia and C. clavifera.*

Finally, with regard to *C. imbricata* and *C. Chemnitzia*, the latter, in its organization, mode of growth and occurrence, corresponds exactly with *C. uvifera*. The differences are only of a morphological nature, and only apply to the form of the branchlets, *i. e.*, *C. Chemnitzia* (fig. 27) has quite cylindrical branchlets at the base of the vertical axis. *C. Chemnitzia* is also, in accordance with its organization, a form which occurs by preference in still water deeper down often together with *C. uvifera*.

C. imbricata (figs. 37—42), on the other hand, is a species which seems to prefer the upper littoral region. It is as a rule closely tufted (fig. 37), which gives it a certain likeness to *C. nummularia*. It might be characterized as a *C. peltata* in which the branches have contracted, so that the vertical axes are very short as are also the branchlets, while they are almost pressed together, thus forming an almost continuous assimilation surface. The detailed description of the species will also show that there are certain transition forms between *C. imbricata* and *C. parvula*.

This *C. imbricata* grows on coral reefs together with *C. clavifera* and *C. nummularia*, but is far less frequent, and does not occur on strongly exposed parts. So, on the reef at Galle, this species was only to be met with on the more sheltered rocks below the Clippenberg Bastion and the Neptune Bastion. It is evident that the form points to a surface enlargement of the assimilation system, if we compare it with *C. nummularia* and *parvula*, since isolated branches grow up vertically and become covered with assimilation discs (figs. 41, 42). But this also involves greater danger of laceration, as the strain is increased. It seems, therefore, as if *C. imbricata* may be conceived as a variant of the *nummularia* type that has increased its assimilation system, and that occurs where the external circumstances do not stand in its way.

(C).—*C. sertularioides type.*

It follows from what has been said above that the bilateral *Caulerpa* forms in common are to be met with in deeper regions, whereas the radiate forms in general have their main distribution in the littoral region. Certain of the radiate species are replaced in the uppermost littoral zone by more or less dorsiventral species.

It is to be noted, however, that in the Ceylon marine flora a typically bilateral Caulerpa also occurs in the uppermost parts of the littoral region, viz., *C. sertularioides* (figs. 7-10). I have already pointed out above the advantages and disadvantages which are connected with the bilateral shoot form in general, which may be shortly characterized as follows :—the assimilation surface is extended, but this, on the other hand, is accompanied by an increased risk of laceration. As a matter of fact, all the bilateral

Ceylon *Caulerpa* forms are more or less lobed, even the deep water forms. Furthest in this respect goes *C. sertularioides*, which has very fine branchlets, whereby the whole shoot axis has the appearance of a feather (fig. 10), to which it owes its former name of "*plumaris*." Strictly speaking *C. sertularioides* is closely allied to the radiate forms in that its branchlets are cylindrical and subulate, and it need only develop these radially as in *f. Farlowi* or *C. Selago*, for the organization to be perfectly radial.

C. sertularioides occurs on the shores of Ceylon in a number of different forms. It is very common in the uppermost exposed littoral region on coral reefs and rocks in the south-west. It is often of low growth with the branches at the top as if chopped off sharp (*f. brevipes*, fig. 7). The branches are now very fine, now somewhat coarser and with coarser rhizomes. The latter seems to be the case especially on sandy bottom as at Jaffna. Sometimes it also seems able to form small tufts (fig. 8). It often grows, as we have said, in very exposed places, and the feather-like axes wave to and fro in the swell. It is clear that such fine subulate branches are very well adapted to a species with such a mode of growth. In this respect *C. sertularioides* corresponds with *C. lætevirens f. cylindracea*, of which it also reminds us in its mode of growth, even if it does not occur in such exposed places as the latter.

C. sertularioides also occurs in the deeper parts of the littoral region, as for instance at Weligama, from a depth of about 3 metres. Johs. Schmidt has also collected this species in 1-2 fathoms of water. In this case it has a somewhat different appearance (*f. longiseta*). It is longer, weaker, and not chopped off sharp at the top (fig. 10). I observed quite similar forms in dark cavities in coral masses on the reef at Galle, so that it seems very probable, in my opinion, that this lengthening of the axis in dark localities and its shortening in intensely bright must be attributed to the influence of light.

4.—On the Difference between Morphological and Adaptational Characters in Caulerpas.

It should follow from what has been said above that *Caulerpa* can scarcely, in contrast to other plants, lay claim to be able to show a multitude of variable types in which no correspondence can be traced between the outer form and the surroundings, which Reinke has presumed. As I think I have shown, several *Caulerpa* species, *e.g.*, *lætevirens*, are as evident ecologisms as one could wish, and different localities are characterized by different *Caulerpa* types.

The different localities are characterized by differences in the bottom (sandy bottom or rock), by different degrees of exposure to the swell, by different depths, and by different intensities of light—and all these differences in environment correspond with differences in organization. Thus, the sand Caulerpas (*C. Freycinetii*, *cupressoides*, *Lessonii*, *Fergusonii*, and others) are distinguished by their long creeping rhizomes with finely branched roots, whereas the coral and rock Caulerpas (*C. clavifera*, *nummularia*) are often far less elongated, and their root system consists of adhesive roots with rather few and short branches. Then we find that in more exposed localities—besides that the adhesive organs are more strongly developed—the assimilation axes approach the cylindrical, at the same time being very narrow, *i.e.*, offer the least possible opposition to the tearing power of the waves (*C. verticillata*, *lætevirens*, *f. laxa*, *sertularioides*). On the other hand, the branchlets are numerous and cylindrically arranged so that complete exposure is favoured by the continuous movements in the swell. The different depths at which the Caulerpa lives is reflected in the organization ; the deep forms are often leaf-like and reach the highest dimensions (*C. scalpelliformis*, *pinnata*, *taxifolia*) : the surface forms have a shortened axis system, while at the same time the whole assimilation system is extended at the sides in one level (*C. clavifera*, *nummularia*, *parvula*), whereby also the assimilation discs themselves strive, as it were, to extend horizontally (*C. nummularia*).

Reinke, as is well known, is of the opinion that in Caulerpas there is no difference between so-called " morphologischen und Anpassungsmerkmale," so that " Wer es liebt, auf die Unterscheidung von morphologischer und Anpassungsmerkmale Werth zu legen der wird daher die Speziescharaktere von *Caulerpa* sowohl zu den ersteren wie zu den letzteren rechnen müssen." ("Ueber Caulerpa," p. 68.)

But in this connection we need only refer to the parallel between *C. clavifera*, *C. uvifera*, and their forms on the one side, and *C. nummularia*, *peltata*, and *parvula* on the other, to prove that REINKE's assertion cannot be justified, for the "Species-character" in the former group is the *ball-shape* of the small assimilation branches, in the latter their more or less *disciform* shape. But the "Anpassungs-charactere," on the other hand, are the different lengths of the rhizomes and axes which form the analogy between *C. clavifera-nummularia* and *C. uvifera-peltata*. And between them as a transition form, or rather as a primary form common to both, stands *C. Chemnitzia*, which in its organization shows a faculty to develop in the one or the other direction, thus less markedly differentiated or adapted than the other two groups.

If what REINKE says about *Caulerpa* were really a fact, it would be most remarkable and would alone justify these algæ in taking an exceptional place in the vegetable kingdom. For the opinion of the biologists of our day is inclined to recognize that it is justifiable to distinguish between organization characters and adaptational characters. So, for instance, Professor GOEBEL said in his lecture at the Congress of Arts and Sciences in St. Louis, 1904, "The Fundamental Problems of Present Day Plant Morphology" ('Science' N. S., Vol. XXII. No. 550, 1905): "In reality it seems to me that morphological comparison as well as experiment shows that the distinction between organization and adaptational characters is justified." This principle may be said to hold good, as I have tried to show, also of the many changing forms of the genus *Caulerpa*.

III.—ON THE DIFFERENT KINDS OF VARIATION IN CAULERPA.

1. CONTINUOUS VARIATIONS IN SHOOT BRANCHLETS (PINNULES) FROM BASE TO POINT

The variations often point to a surface increase.—Comparison with the heterophylly of the higher plants.

In the foregoing I have shown the differences in the organization and structure in the shoots of *Caulerpa*, which are to be looked upon as adaptations to different modes of life. Thus we have seen that the shoot systems of many surface living Caulerpas are closely connected with the conditions of the light and the exposure to sea and wind that exist in the littoral region, and that when the Caulerpas grow in deeper and calmer water they assume other larger and more branched and taller forms. In all these cases the relation between organization and locality is evident.

But in this genus there is another kind of variation in the shoots, between the forms of which and the external conditions of the plant no such direct relation can be traced. It is the multitude of these variations that seems to have caused the difficulties in determining the definitions and limitations of the species in this genus. That Madame WEBER v. BOSSE has kept in sight these different variation types can be seen from what she says on p. 245 in the "Monographie des Caulerpas:" "La question sur la valeur des espèces.....est d'autant plus difficile à resoudre puisque le thalle à structure continue de ces algues, subit une grande influence du milieu où il pousse, et que la même plante adopte en outre des formes très diverses, sans qu'on puisse trouver une raison quelconque pour expliquer l'apparition de formes si variées au même stolon." It is precisely this variation that has been so sharply accentuated, both by Madame WEBER v. BOSSE and by Professor REINKE, that the variations according to localities have been almost entirely overlooked.

The variations that are not directly dependent on locality are mentioned by Madame WEBER v. BOSSE on p. 246, and are either characterized by the branchlets or pinnules of an assimilator being of a different form at the base than at the point, or there shoot out from the same horizontal axis dissimilar assimilators, in that some have exclusively one kind, other exclusively another kind of branchlets. Lastly the variation can also consist in the branchlets being arranged in a varying number of rows, though the branchlets be similar among themselves.

Here it may happen either that assimilators with a different number of branchlets shoot up from the same horizontal axis, or that one and the same assimilator may have branchlets with a number of rows varying at the top and at the base.

For a discussion of these different variations and their nature it is perhaps advisable to begin by describing some special cases. Let us, therefore, examine some Ceylon Caulerpas which show a variation of this kind.

Among other forms of *C. uvifera* from the islands around Jaffna I observed one which I have described under the name *f. planiuscula* (fig. 16). It shows a series of transitions in its branchlets. At the base they are all ball-shaped, without exception, but a little higher up they begin to grow more and more flattened, at first hardly noticeable, afterwards very evident. At the top of the assimilators the greater number of the branchlets are more or less flattened, whereas at the base no such branchlets at all are to be seen.

An analogous variation of the branchlets is to be observed in *C. corynephora f. complanata* (fig. 18). The main axis is flat, with the branchlets in two rows. At the base these are of the same width, but higher up they swell out at the points, so that they have the appearance of being somewhat constricted. The transition between the different kinds of branchlets is gradual, without sharp contrasts.

To some extent of the same kind is the variation in *C. dichotoma* (figs. 23, 24), in that in this species too the basal branchlets are simple and the dichotomous ones only begin higher up, but in this species we have, besides this, to note that the branchlets at the base are arranged radially around the axis, whereas the bifurcated branchlets higher up are arranged predominantly in two opposite rows, whereby the whole assimilator becomes bilateral. Moreover it sometimes happens that some assimilators have only simple radially arranged branchlets. *C. dichotoma* thus shows an example of different kinds of variation of branchlets.

C. peltata (figs. 31-33), on the other hand, shows somewhat different kinds of variation; either an exclusive increase in the assimilation discs, the intervals being then longer, at the same time as the branchlets only develop from the upper side of the side branches, which thus become dorsi-ventral (fig. 32), or some branchlets develop in the direction of the spherical form, showing a tendency to swell up (fig. 33). The larger assimilation discs in the former variety, as well as the swollen ones in the latter, occur at the tops of the shoots, whereas the base is surrounded by the more numerous but smaller assimilation branchlets.

Of about the same kind is the metamorphosis of the branchlets or pinnules in *C. Chemnitzia* (fig. 26–30). At the base they are more or less pronouncedly cylindrical (fig. 27), of about the same shape as in *C. lætevirens*; higher up they become trumpet-shaped at the top and as if abruptly cut short. At the very top the branchlets are either disciform in certain varieties (fig. 29), which have a tendency in the *peltata* direction, or spherically swollen in others which thus approach the *racemosa-uvifera* series (fig. 30).

In all the forms of variation in the branchlets described above it is a common feature that the variation proceeds more or less regularly, step by step, and furthermore that a tendency to surface increase is apparent, though it is effected in different ways; for it is evidently shown in *C. corynephora f complanata* (fig. 18), *dichotoma* (figs. 23, 24), *peltata* (fig. 32), *Chemnitzia* (fig. 27), and also to some extent in *uvifera f. planiuscula* (fig. 16).

REINKE, in his treatment of the variations of *Caulerpa* (*loc. cit.* p. 87), has distinguished between such as pass over "allmählich" and such as pass over "sprungweise," *i.e.*, "gradually" or by "leaps and bounds." The variations in question are apparently identical with those REINKE has characterized as "allmählich."

It is indisputable that this metamorphosis of the branchlets reminds one in many respects of the heterophylly of the higher plants. It can, however, be of an essentially different kind, in that the difference between the younger and older leaves is bound up with different conditions of life during different phases

in the life of the plant, or else such different conditions do not occur, but the heterophylly depends on the first developed leaves being arrestment stages (" Hemmungsstadien ") of the fully developed ones.

Are they then arrestment stages of the same kind as the primary leaves, as for instance the simple leaves of Leguminoseæ with otherwise normal compound leaves? Yes, to a certain extent they are quite analogous with them. Thus, the basal branchlets of *C. dichotoma* (figs. 23, 24) are undoubtedly much simpler than the later dichotomous ones, and there is nothing that debars our considering these simple branchlets as arrested stages of the other ones. The same may be said to apply to *C. corynephora f. complanata* (fig. 18) and *C. Chemnitzia* (figs. 24, 29) and other species with simpler branchlets at the base.

But, on the other hand, certain reasons offer definite testimony against our explaining all the differences in the development between base and top as arrestment phenomena. So, for instance, *C. Lessonii* offers an example (fig. 11) of the branchlets at the base being arranged in many rows, *i.e.*, are more numerous at the base than higher up. The same is also the case with the *f. tristichophylla* of *C. axifolia* (fig. 5) and several *cupressoides* forms. For in these *more* rows of branchlets are developed at the base than higher up, and this can scarcely be characterized as an arrestment, but rather the reverse. Every case, therefore, mentioned above must not be looked upon as an arrestment stage.

But cannot the different forms of branchlets at base and point be explained phylogenetically ? That is, a *Caulerpa* rhizome, which for some cause or other has entered on a new course of development as far as the form of the assimilation branches is concerned, has returned to the more primitive branch form. But by reason of the exclusive propagation of *Caulerpa* by the formation of shoots, the difference between phylogeny and ontogeny is practically *nil*, provided the latter term is not meant to express the history of the limited development of each assimilation axis (= assimilator, REINKE).

There is scarcely any reason to consider indisputable arrestments as reminiscences of phylogenetic evolution. GOEBEL, in his work " Vergleichende Entwicklungsgeschichte der Pflanzenorgane " in SCHENK'S ' Handbuch der Botanik ' (III., 1), has pronounced against such an opinion. Thus on p. 261 he says : " Derartige Erscheinungen (=Hemmungsstadien der Laubblätter) phylogenetisch aufzufassen, dazu liegen glaube ich, kein Grund vor, ich sehe in jenen einfachen Primärblättern nur Hemmungsbildungen, deren Ursachen in Eigenthümlichkeiten des Wachstums oder der Zusammensetzung embryonaler Sposse liegt." In the cases where no objection can be raised against considering the different branches as simply arrestment forms—and such cases exist, as we observed above, also in Caulerpas—there is no valid reason for the hypothesis that phylogenetic phenomena has played a part, but both cases are so similar and analogous that what is the cause of the one kind may well be supposed to be the cause of the other. Experiments alone can decide the point.

But as for the shoots in which the basal branchlets are so far from being arrested that the very opposite is the case, it seems that there is no other explanation possible than phylogeny. It cannot be denied that the resemblance between the basal branchlets of *C. dichotoma* (fig. 23) and the branchlets of *C. lætevirens* (fig. 19) is perfect. The same holds good to almost the same extent of the corresponding branchlets of *C. Chemnitzia* (figs. 26, 27, 28, 29) and *C. lætevirens*. And the basal branchlets of *C. uvifera f. planiuscula* (fig. 16) are typical *uvifera* branchlets, just as basal branchlets of *C. taxifolia f. tristichophylla* (fig. 5) are *C. falcifolia* branchlets, and the basal branchlets of *C. Lessonii* (fig. 11) are *C. cupressoides* branchlets. Examples of the same thing are not uncommon among the Caulerpas in general. Thus *C. plumaris f. Farlowi* (WEBER v. BOSSE, "Monographie," p.295, Pl. XXIV., 4–6) is a form with branchlets running in every direction and is to *C. plumaris* as *C. falcifolia* is to *taxifolia*.

In this respect *C. mamillosa*, regarded by Madame WEBER v. BOSSE as a variety of *C. cupressoides*, is especially remarkable (WEBER v. BOSSE, *loc. cit.* p. 332, fig. 6, Pl. XXVIII.). Its base is surrounded by globular branchlets, which forcibly remind one of certain forms of the *pedicellatæ* group (for instance, *C. lentillifera*, compare fig. 6, Pl. XXVIII. and fig. 2, Pl. XXXIV. in WEBER v. BOSSE, *loc. cit.*). Similar examples could be multiplied. These examples show clearly how the development of the branchlets may

be conceived as having taken place. Whatever the factors were that produced them, the changes (metamorphoses) proceed precisely as in other plants, in that these factors must be considered to have exercised a transforming influence upon the embryonal substance in the growing point itself, and this results in a successive transformation of the branchlets in some direction which then is either a direct surface increase of the assimilation system (*C. dichotoma*, figs. 23, 24) or a transition of the assimilation from several branchlets placed in many rows round a cylindrical axis to only a few but opposite rows of branchlets on a flattened but broader main axis. It follows then that a study of the metamorphosis of the branchlets can give us some serviceable hints for the solution of the question of the evolution of the different *Caulerpa* species, and hence of the system and phylogeny of the whole genus.

Thus, for instance, it seems to me that such a form as *C. lætevirens*—at least as far as its assimilation branchlets are concerned—is a very primitive type, because this form of branchlets reappears at the base of so many other forms, as *C. dichotoma*, *Chemnitzia*, and several of WEBER v. BOSSE's *uvifera* and *clavifera* forms, which must thus be considered as younger than and derived from *lætevirens*. (Cf. figs. 3, 8, 18, &c., Pl. XXXIII., WEBER v. BOSSE, *loc. cit.*). In the same way forms with the branchlets radially arranged around cylindrical axes must be considered as more primitive than the bilateral forms, because one often meets with axes with the branchlets at the base radially arranged, higher up bilaterally, but not the other way about. Also some Caulerpas with articulated base, but for the rest with very varying and different shape, show, in my opinion, that the articulation is a very old and primitive character, while their form otherwise must be considered as something that has arisen in relatively recent times. In any case they are undoubtedly younger than the truly articulated species of *Caulerpa*.

In general, the earlier stages phylogenetically are very strongly pronounced in such plants as have been developed under extreme conditions, very different in nature when compared with those under which their ancestors lived. So Xerophytes, Hydrophytes, and climbing plants are often characterized by a pronounced heterophylly, the explanation of which must be looked for in their phylogenetic evolution, even if the plant's present mode of growth can be an explanation for its being so differently organized at different periods of its life.

As for the Caulerpas, it seems that no such sharply pronounced difference exists, with respect to their external conditions of life, as may explain the cause of the different development at base and point. But, in the foregoing, we have seen that the localities of the species of *Caulerpa* can vary not inconsiderably. So *C. lætevirens* is confined to strongly exposed localities where its position is not threatened by any other *Caulerpa*, and we have seen that its organization is an adaptation to precisely such surroundings. It is highly probable that this or some similar form under altered conditions of life has given origin to forms, such as *dichotoma*, and *Chemnitzia*, both of which could be derived from *lætevirens*. In both these species in the upper branchlets an increase of the assimilation surface takes place, but it is produced in different ways : in *dichotoma* (figs. 23, 24) by the cylindrical branchlets being flattened out and becoming leaf-like and, finally, bifurcated at the top; in *Chemnitzia* (figs. 27, 29) by the branchlets expanding trumpet-like, being more sharply cut short at the top, and finally being perfectly disciform. In both cases very similar results are produced, but in different ways. To this we must add that both these forms, *C. dichotoma* and *Chemnitzia*, are still-water forms in comparison with *C. lætevirens* and the gradual metamorphosis of the branchlets can thus be seen in connection with the changed conditions of life, which allow a surface increase of the branchlets that in *C. lætevirens* is perhaps made impossible by its mode of life, *i.e.*, by the external conditions in which it grows. Therefore, of course, the external conditions can very well be considered in this genus too as the factors that produce a transforming influence on the growing-point by irritation, and through that the whole organization of the plant. Why the development in the one case takes the direction of flattened leaf forms, and in the other of trumpet-like ones, is a question that cannot, of course, be answered by deductions from the above facts. Now, at the base of the branches in the derived species, branchlets are still developed of the more primitive kind which entirely covered the axis system of the parent form, in the same way as *Acacia* seedlings *in their youth* develop

primary leaves like those in other species of *Acacia* and only develop phyllodes later on. It, therefore, seems that, also in Caulerpas, the base of the shoot has retained most of the character of the parent form.

The differences in the formation of the shoots, which I have just dealt with, are characterized by the different kinds of shoots originating successively in the same main axis ("allmählich erfolgend," REINKE) or, in other words, they are an example of differences in organogenesis at different stages of development in the life of the shoot, *ergo*, analogous with the early forms ("Jugendformen").

Closely allied are the cases in which, from the same horizontal axis, vertical axes shoot out, each with its several special kind of branchlets (a "sprungweise erfolgende" variation, REINKE); for, usually, the different vertical axes are to some extent individualized, so that the branchlets in different axes are transformed at unequal rates. Thus, for instance, we can see one axis in which the primitive form of the branchlets covers the axis rather high up, another in which they only occur at the base and abruptly pass over into the definitive form (Cf. fig. 11 of *C. Lessonii*, the branchlets to the left).

If, now, the case occurs that in one axis the primitive forms are very few, or even entirely wanting, and that the opposite is found in another, that is to say, that there is nothing but primitive forms, it results that from one and the same horizontal axis quite different vertical axes may derive. In this form of variation, however, there are always transition forms, which show how the different axes may have arisen. The same is the case when the difference between the vertical axes only consists in their branchlets having developed in a dissimilar number of rows (Cf. fig. 45 *a*, *b*, of *C. longistipitata*). It is precisely these differences that REINKE has kept in view in distinguishing the variations in the two kinds "allmähliche" and "sprungweise" (*loc. cit.*, p. 87), and he characterizes the difference thus, that in the one we have to deal with a little, in the other with a big bound ("sprung"). According to him, there is no other difference.

It is one very characteristic trait in all the shoot variations we have been speaking of that they occur successively, *i.e.*, with transitions that may be more or less pronounced; another that they may to some extent be connected with changes in the mode of life, to which they can be conceived as adaptations or "ecologisms." The more primitive forms of branchlets at the base may be explained by the base of the shoot having kept more of its primitive character, a character more closely allied to that of the ancestral form. Therefore they must be explained phylogenetically.

(2) *Discontinuous Variations—Atavistic reversions or mutations?*

Quite different from all the other kinds of variations are those that occur in *C. Lessonii f. uticorinensis* (fig. 12). Here we have three different kinds of branches, narrow ones with two-sided and three-sided branchlets, like those in *C. cupressoides*, and furthermore, and this is the most noticeable point, considerably broader ones whose very presence shows their affinity with *C. Lessonii*. The last-named kind occurs abruptly without any intermediary transition form, and corresponds in this respect, as REINKE has pointed out ("Ueber Caulerpa," p. 85) in a striking way with the bud variations we know in such higher plants—especially trees—as can be referred to under the name of "sporting plants" (DARWIN).

Another example of the same phenomenon is the plant I have called *C. sedoides f. mixta* (figs. 49, 50). The branchlets are, as a rule, ball-shaped with or without stalk, but among them shoots out occasionally a perfectly cylindrical branchlet, three or four times as long as the others, and without any transition at all. *C. sedoides f. mixta* thus shows an example of an abrupt variation of branchlets or pinnules, whereas *C. Lessonii* shows an example of similar variation but of long branches or whole assimilators. That these variations are of quite a different kind to all the others I have dealt with in the foregoing chapter is evident, and the difference lies not only in the abrupt transition, but rather in that no correspondence with any external conditions at all, no adaptations, can be traced in this metamorphosis.

Bud variations (DARWIN) or the so-called vegetative mutations have been dealt with at length in DE VRIES' "Mutations-theorie" (Band, II., p. 670). According to him, these can be divided into three

different groups: bud variations due to the vegetative cleavage ("Spaltung") of bastards; bud variations due to vegetative atavism in so-called middle races ("Mittelrassen"); thirdly, the real bud variations, which again may be of two kinds, viz., such as are of atavistic nature and such as are not of atavistic nature but are progressive mutations (vegetative mutations).

As no other propagation than by shoot formation occurs in the Caulerpas every kind of variation due to bastard formation is, of course, absolutely out of the question. There remain, consequently, bud atavism and real mutation. If, now, it is of the former kind, the changes that take place in the appearance of the shoot must therefore correspond with those of ancestral forms. Since no absolute certainty can be arrived at in this matter, we must content ourselves with examining whether possibly any now living species normally possesses branches of a kind which in another species appears as bud variation. If so, it would support the supposition that atavistic phenomena are present.

If we now examine *C. sedoides f. mixta* (fig. 50) which afforded us an example of such a bud variation, it will appear that its elongated or irregular branchlets have the very same form or, at least, are very similar to those in *C. ambigua*, which belongs to the same group as *C. sedoides* (Cf. my fig. 50 and Pl. I., figs. 4, 6, 7, 14 in Okamura, "On the Alg. of the Ogasawara-jima" (Bonin Islands).

It thus seems by no means improbable that *C. sedoides* is derived from a species which has been very closely allied with or similar to *C. ambigua*. That cylindrical branchlets (= pinnules) are more primitive than spherical ones I have already tried to show in the foregoing, while dealing with the question of relationship between *C. racemosa*, *lætevirens*, and *Chemnitzia*. In complete analogy with this is, too, that such species as *C. ambigua* must be considered as more primitive than *sedoides f. crassicaulis*. Everything, therefore, points to the conclusion that the bud-variation in *C. sedoides f. mixta* should be regarded as an atavistic reversion.

Whether the same is the case with *C. Lessonii f. tuticorinensis* is somewhat more difficult to decide. The form which I have indicated as the main species of *Lessonii* (fig. 11) shows at the base branches with three-sided branchlets; thus, in conformity with the opinion I have attempted to vindicate, it s derived from a species with three-sided branchlets, *i.e.*, from one of the *cupressoides* forms. *C. Lessonii f. tuticorinensis* (fig. 12) also has the prevalent number of branches of the common *cupressoides* form; two-sided as well as three-sided, and the great majority of the branches never have a different appearance. But amidst these branches the broad flattened ones with their two-sided branchlets are formed just as bud variations. These are from the very beginning two-sided, and not, as often in *Lessonii*, three-sided at the base. It is therefore impossible to say that the broad flat branches in *C. Lessonii f. tuticorinensis* are reversions to *Lessonii*, for that would mean that *Lessonii*, that is the broad flat leaf form, were more primitive than the *cupressoides* branches. But this is contradicted by *C. Lessonii* itself, in which the development shows the exact contrary (fig. 11). This does not seem to support the atavistic nature of these shoots; yet it seems impossible to look for any definite solution of this problem at the present time. It may be possible for *Lessonii* and *C. Lessonii f. tuticorinensis* to be in the nature of parallel forms of equal rank, both deriving from a *cupressoides* form and with a tendency to form flat bilateral branches. But in the one (*Lessonii*) this tendency is the predominant, and has so to speak become the normal one, while in the other one (*tuticorinensis*) this tendency is more latent and only rarely reveals itself. This is of course a pure speculation, and for the solution of this, as of so many similar questions touching variation in *Caulerpa*, experiments and cultures are necessary which the traveller in the Tropics has difficulty in arranging.

That both these forms go together seems to me indisputable, and I have wished to give expression to this by calling one form the *f. tuticorinensis* of the other, *Lessonii*. But with this I do not imply that *Lessonii* is necessarily more primitive, for here, as in so many other cases, the first form to be distinguished becomes the main species, the later ones the variations, though with equally good reason the reverse might have taken place.

3. *Dwarf Forms.*

Stunted dwarf forms are often looked upon as a special kind of variation. These, too, are not rare among Caulerpas. Dwarf forms in general are produced by poor nourishment, and it is to be assumed that this has also in some way occasioned the *Caulerpa* dwarfs. And it seems to be clearly the case in *C. taxifolia f. interrupta* (fig. 6), in which stunting has perhaps been produced by lack of light, owing to the great depth, for *Caulerpa*, at which it grows (more than 10 m.). In the other cases there are, on the other hand, no directly apparent external circumstances which could justify our calling the cause poor nourishment. On this point, however, it is impossible to pronounce with any degree of certainty, since our knowledge of the requirements in nourishment of the algæ is still so fragmentary. If, now, it is some deficiency or other in the nourishment that has caused them, this type of variation must, according to present day opinion, be classed under fluctuating variability among the different kinds of branchlets, and deserves then to be distinguished at the most as local forms. If, on the contrary, these dwarf forms occur not simply isolated among the normally developed ones, but show a certain constancy within a given district, it is more probable that we have to do with special races. For it is evident that, since we do not know what influence the different external conditions and especially those of nourishment exert, and since we have no opportunity of conducting cultural experiments, it is absolutely impossible to determine objectively whether we have to do with individual variations or with races with constant character. In such cases it must often be a matter of taste for the taxomonist if the plant in question is to be classed as a race or only as a local form.

The dwarf forms that I observed in Ceylon were : *C. taxifolia, f. interrupta* (fig. 6), *C. plumaris, f. umbellata* (fig. 9), *C. lætevirens f. depauperata* (fig. 20) and *C. parvula* (figs. 43, 44). Of these it seems to me that some doubt arises only in the case of *C. parvula* (fig. 44), *i.e.*, whether it is not rather to be regarded as a distinct species, since, at Beruwala, where I collected it, it occurred in several places and seemed to be a more or less constant species. I have, therefore, classed it as a separate species. As for the others, they showed all the signs of being mere accidental varieties, which diverge so much, however, that I think we are justified in distinguishing them as special forms.

4. *Summary.*

In the preceding we have thus got to know different kinds of shoot variations which can occur in one and the same *Caulerpa*. And we have seen that these are of the following kinds :—

1. Variations which depend on the locality, and which are to be considered as adaptations or ecologisms.
2. Variations which cannot be considered as ecologisms, but which are the result of fluctuating variability amongst the different branchlets (= pinnules).
3. Variations which can be considered as phylogenetic stages of evolution (for instance, that the basal branchlets or pinnules are of more primitive form than the upper branchlets).
4. Bud variations of atavistic origin (*C. crassicaulis f. mixta?*).
5. Dwarf forms.
6. The variations which do not fall under any of the above categories may, lastly, be bud variations without atavistic origin (= mutations).

As Reinke has pointed out, it is to be noted especially about *Caulerpa* that no sharp line can be drawn between individual variations and bud variations owing to their characteristic mode of propagation, since all the *Caulerpa* individuals originate as buds on a common horizontal axis, and thus all variations are bud variations in the widest sense of the term. (Cf. the relation between ontogeny and phylogeny in *Caulerpa*, p. 16.)

All these factors again work together and cause the multifarious diversity of *Caulerpa*. And here it is to be noted—as several writers have already pointed out—that all this diversity and all these variations

depend exclusively on changes in the purely vegetative sphere, for no organs of fructification nor spores of any kind are to be found in these plants, and REINKE has, therefore, hit the mark when he says *that the somatic plasma is the medium in and through which the variations of the Caulerpas originate.*

IV.—TAXONOMY OF THE CAULERPAS.—DEFINITION OF THE SPECIES.

It is clear that, as long as we have no firm basis for determining the factors which cause the formation of a species, we can have no real objective principles by which we can determine its limitations. It is for this reason that the conception of the specific character of a species varies more than anything else in the different works on Caulerpas. While some authors prefer small but often less sharply distinguishable species, others prefer wider species, under which are classified a huge number of sub-species, varieties, and forms, often without it being possible for the reader to explain why a certain form should be called there "variety," now only "form."

In this respect also the Caulerpas have been subjected to various fates. LAMOUROUX, the founder of the genus *Caulerpa*, knew 10 species in 1809. Since then new species have been described, one by one, and KUTZING could enumerate 41 species in 1849, divided by him into several genera. The first really valuable monograph on the genus *Caulerpa* was published by J. G. AGARDH in 1872, and he could then distinguish no less than 64 species divided into 13 groups. In 1898 Madame WEBER v. BOSSE, in her monograph, reduced the number of the species to 54, but these species have numerous sub-species and varieties of different rank. It is undoubtedly a great merit in her work that thereby the unity, the great affinity between the various forms, is so strongly accentuated. But, as REINKE so felicitously points out, it is not necessary to group together different species even if transition forms can be found between them. For besides the practical difficulties that accompany such a taxonomy—for one is forced to use as many as four different names (species, sub-species, variety, form) to make quite clear what one is refering to—so too from a purely theoretical point of view one must note that one might just as well reduce the whole genus to one, or a few species, dependent on whether one assumes a monophyletic or polyphyletic origin. But systematic botany ought to lay stress not only upon unity but also upon diversity, and from this point of view it seems more satisfactory to me to employ a more limited species definition, as the older authors did. The genetic relationship of the different species is then not confused, at any rate.

If we apply this to the Ceylon species of *Caulerpa* it is really only the group *clavifera-uvifera-lætevirens-Chemnitzia-peltata* that makes difficulties; for in this group the diversity is greatest. While some *Caulerpa*-species, as *verticillata*, *crassifolia*, *sertularioides*, are less variable, the *racemosa* group (WEBER v. BOSSE) on the other hand, as observed above, is especially rich in forms. It is evident that the genus *Caulerpa*, as so many other genera of plants, shows types of different constancy. While some species vary but little, in other groups the variety is very great and probably new forms are now originating. It is thus probable that in Ceylon this is the case with forms belonging to *clavifera*, *uvifera*, *Chemnitzia*, *peltata*, *nummularia*, and others. In this connection it must be observed that geographical distribution in some cases quite clearly shows that the different groups of forms have in part a tendency to have a distribution which excludes other groups; so, for instance, *C. Chemnitzia*, *uvifera*, and their forms occur especially in the north of Ceylon, whereas *C. clavifera* and *nummularia*, have more predominantly southern distribution. This may possibly be bound up with the conditions of life being so different in different parts of the Island, coral-reefs and rocks in the south, sand in the north.

But with respect to the geographical distribution of these algæ in Ceylon and its causes, this problem, until I have had an opportunity of studying all the algæ of the island, can only be dealt with by me cursorily

V.—ON THE GEOGRAPHICAL DISTRIBUTION OF THE CAULERPAS.

1. The Distribution of the Caulerpas in Ceylon.

Different Species in the North and in the South.

The Relationship between the different External Conditions in the North and in the South.

In this chapter, finally, we shall deal with the occurrence and geographical distribution of the Ceylon species of *Caulerpa*.

The first question we have to answer is, How are the Ceylon Caulerpas distributed in Ceylon? Here, of course, it is to be noted that of the twenty odd *Caulerpa* species in Ceylon, only relatively few, about a third, occur so abundantly that they leave their stamp on the vegetation as a whole. The others occur only sparsely and scattered about, and cannot be classed as plants characteristic of the marine flora of Ceylon, even if they sometimes may occur quite locally in such numbers that they form real associations of their own (*C. verticillata*, *C. lætevirens*.)

Species which occur more or less abundantly and which—in large districts, at least—are very characteristic elements in the Ceylon algal flora, are *C. clavifera*, *uvifera*, *Chemnitzia*, *peltata*, *nummularia*, *imbricata*, and possibly even *sertularioides*. Of these *C. sertularioides* occurs scattered along the whole coast, never in great masses, but always rather isolated, hemmed in between other algæ. The others, on the contrary, occur in great quantities, and contribute in many places to give the algal vegetation as a whole its stamp. Here it should be observed that *C. clavifera*, *nummularia*, and *imbricata* occur especially in the south-west and in the south (Colombo–Tangalla), while *C. uvifera*, *peltata*, *Chemnitzia*, have a more pronounced northern distribution (Gulf of Mannar, Jaffna, Trincomalee). These groups, it seems to me, confine themselves to provinces of their own to a certain extent. Here, again, it is to be observed that the species that have a main distribution in common are also characterized by a certain resemblance in organization. So for instance, *C. clavifera*, *nummularia*, and even *imbricata* are characterized by relatively short vertical axes, which gives rise to a more mat-like mode of growth so that the whole assimilation system is on the same level. On the other hand, both *uvifera* and *peltata*, as also *Chemnitzia*, have lengthy vertical axes that wave in the swell, and thus they form quite a different type of organization.

These differences in organization and distribution of the different species are concurrent with the external conditions of algal life being so different in north and south. In southern Ceylon the coast is partly rocky and the rocks there are often fringed by splendid coral-reefs; whereas, in the north around the islands at Jaffna and at Adam's Bridge, the shores are shallow sand beaches with loose bottom where fringing coral reefs rising to about the level of the sea are lacking.

I have already dealt above with the differences in organization that usually accompany these different external conditions, and it is very remarkable that the short-axed *clavifera*, the most common *Caulerpa* on the coral reefs of south-west Ceylon, is replaced in the north by the closely related long-axed *uvifera*, in the same way as *C. nummularia* and *imbricata* in the south are replaced by the allied *peltata* and *Chemnitzia* in the north. All these species, as is known, are very closely related, and have also been classed by Weber v. Bosse as one single broad species, *C. racemosa*, *sens. ampl.* ("Monographie des Caulerpas," p. 356) with a great number of sub-species, varieties, and forms. For practical as well as scientific reasons I have deemed it advisable to prefer a more narrow definition of the species, but this does not affect the fact that all these species and forms are genetically very closely related. With respect to the form of the pinnules, *C. clavifera* is allied to *uvifera* just as *nummularia* is allied to *peltata*; but from the point of view of organization in general we must group them differently, since then *clavifera* and *nummularia* show themselves to be representatives for one type, *uvifera-peltata* for another. I have already in the preceding given these plants as examples of the fact that also in the genus *Caulerpa* there is—as against what Reinke tries to prove—a difference between morphological and adaptational

characters. And now we see that this difference in adaptational character most closely corresponds with the distribution of the species, so that similarly organized species have a common centre of distribution. This clearly follows from what has been stated above, *i.e.*, that especially *clavifera* and *nummularia* have quite another distribution than *uvifera-peltata*. And since the characters which separate these two groups are to be regarded as adaptations to the external conditions within the respective distribution districts, these closely related species, their organization and distribution, may be given as examples of the principle (WETTSTEIN, "Grundzuge d. geogr.-morphol. Methode d. Pflanzensystematik," p. 30) that forms or species which are adaptations to external conditions with a limited distribution also themselves have a distribution which coincides with that of the conditions in question.

To the less common forms of *Caulerpa* that occur in Ceylon belong the following species :—

C. verticillata	*C. corynephora*
C. scalpelliformis	*C. lætevirens*
C. crassifolia	*C. dichotoma*
C. taxifolia	*C. parvula*
C. Freycinetii	*C. longistipitata*
C. cupressoides	*C. sedoides*
C. Lessonii	*C. Fergusonii*

Of these *C. verticillata* has only been observed at Galle, Colombo, and at Tuticorin in South India ; at the first-named place locally but abundantly and forming a special association. The species is not noted from the east coast, nor from the islands and banks which form Adam's Bridge. It is thus predominantly of a western distribution in Ceylon.

C. scalpelliformis, which is probably a deep water form, is only known from the Gulf of Mannar (Pearl banks, Paumben, Tuticorin).

C. crassifolia and *taxifolia* have similar distribution ; the former is the rarer and has been observed from Weligama in the south to as far as the north end of the Gulf of Mannar (Pearl banks and Paumben) ; the latter at several places within the same district.

Several species have only been observed in solitary specimens, as rarities. Of these—

C. Freycinettii (Jaffna)	*C. corynephora* (Tuticorin)
C. cupressoides (Paumben)	*C. longistipitata* (Paumben)
C. Lessonii (Pearlbanks, Tuticorin)	*C. Fergusonii* (Paumben)

have only been observed in the north from the Pearl banks, Paumben, Tuticorin, Jaffna, but are absent from the south-west coast, which has, nevertheless, been the most closely investigated.

On the other hand there are some species with very singular and isolated occurrence, which are only known from the south coast, viz. :—*C. lætevirens* (Galle, Weligama) ; *C. dichotoma* (Weligama) ; *C. sedoides* (Dondra Head, Matara, Weligama) ;* also *C. parvula* is only known from some isolated places (Beruwala in the south-west and Paumben in the north).

If we examine these different species from the point of view of their organization and mode of life, it is remarkable that several of the northern forms prove to be pronounced sand Caulerpas with coarse, horizontal axes, and richly and finely branched roots, *e.g.*, *C. Freycinetii*, *cupressoides*, *Lessonii* *Fergusonii*, besides which *crassifolia*, *taxifolia*, and also *scalpelliformis* join them.

On the other hand it is to be noted that such species as *C. lætevirens*, *sedoides*, and possibly *dichoma*, which have only been observed in the south, are pronounced rock Caulerpas. The species that have been observed especially in the north are, moreover, often deep water Caulerpas—for instance, *C. scalpelliformis*, *C. crassifolia*, *C. cupressoides*, *C. Lessonii*, *C. Fergusonii*—whereas those that have been found only in the south are surface Caulerpas.

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* Note that *f. mixta* has also been observed at Paumben !

From what has been said above it follows that the difference in organization that prevails among the predominating *Caulerpa* species in the north and in the south, and which depends on the difference in the external conditions of life, can also be traced in such *Caulerpa* species as are rather to be considered as being more accidental ingredients in the flora. Here, too, thinning, owing to external influences, makes itself felt, so that, for instance, the rocks and reefs in the south harbour species that in their organization show themselves more fitted for these.

It is remarkable that the north-east coast of Ceylon, as far as we know, has no *Caulerpa* that is not known in other parts of the Island. It is striking, for instance, how at Trincomalee, where the rocks seem to be excellent localities for algae, the marine flora is apparently scanty and, in richness of species and luxuriance in general, very inferior to that on the rocks in the south-west. This fact seems already to have made itself clear to HARVEY, to judge by his disappointment at Trincomalee. (See "Memoir of W. H. HARVEY," London, 1869, p. 251).

2.—THE DISTRIBUTION OF THE CEYLON CAULERPAS IN OTHER PLACES.

Having dealt with the distribution of the Ceylon Caulerpas in Ceylon, we will investigate their geographical distribution elsewhere. But, first, we must remark that the following species are hitherto only known from Ceylon :—

C. imbricata	*C. parvula*
C. dichotoma	*C. Fergusonii*

These, then, must, for the present at least, be regarded as endemic species.

Among the remainder we find that, of the species which make up the main mass of the Ceylon Caulerpa vegetation, the majority are species with very wide distribution—from the Red Sea in the west to the eastern islands in the Pacific, and also in the West Indies. Such species are—

C. clavifera	*C. Chemnitzia*
C. uvifera	*C. peltata*
C. sertularioides	

C. nummularia is not reported from a more western point than Ceylon, and seems to have its main distribution in the Indian Archipelago and tropical Australia. In this connection it must, of course, be borne in mind that such statements about distribution must be taken with some reserve as far as the definition of the species is concerned, as different authors have different interpretations for the various species. Dealing with the distribution of the species, one has therefore always to reckon with the wider sense of the name in question. The restricted species and forms are, of course, much more limited in their distribution.

Of the *Caulerpa*-species that are comparatively rare in Ceylon, the two following have also the same extended distribution (Red Sea, Pacific, West Indies) : *C. crassifolia* and *C. Freycinetii*.

On the other hand, there are several of the rarer species for which Ceylon and the peninsula of India form the western limit of their distribution, as far as we know. Such are :—

C. verticillata	*C. Lessonii*
C. taxifolia	*C. corynephora*
C. cupressoides	*C. sedoides*

and possibly *C. longistipitata.*

The last-named is, be it noted, only found beyond Ceylon in the Gulf of Siam, and has thus its west limit in Ceylon ; but, on the other hand, the closely related *lentillifera* has a still more pronounced west distribution, since it occurs in the western parts of the Indian Ocean (Madagascar).

While, comparatively speaking, so many species have their western limit in Ceylon, *i.e.*, they themselves have a more easterly centre of distribution, it is very striking that Ceylon is not the east limit for hardly more than one species, viz., *C. scalpelliformis*, which together with closely allied forms occurs from the Red Sea to Ceylon in the north and has also a wide distribution on especially the west and

south-west coast of Australia and Tasmania. It is very remarkable that this species is not known from the Pacific, but, on the other hand, it has been collected on the west coast of Africa (Angola), that is, in the Atlantic.

Lastly, Ceylon is the north, or perhaps better the north-west limit for two species, the central distribution of which seems to be Australia, even if they also occur in the West Indies—*i.e.*, *C. laetevirens* and *C. sedoides*. For the former, the central distribution of which seems to be North and West Australia, southern Ceylon is certainly the north limit. *C. sedoides* has similarly its central distribution in Australia, but occurs also in the Gulf of Siam ; it is also found in the West Indies. In any case, Ceylon forms its north-west limit, and it occurs there only on the south coast, not in the north at all.

We find, therefore, that the main mass of the Ceylon Caulerpa vegetation consists of many species with extensive distribution (from the Red Sea in the west across the Indian Ocean to the Pacific Islands in the east, together with the West Indies), but also of several species with a more easterly main distribution for which Ceylon and India form the western limit.

Finally, the Ceylon Caulerpa flora harbours some Australian elements and one species with a pronounced western distribution and, of course, the endemic species mentioned above.

(3) The Geographical Distribution of Caulerpa in General.

In this last chapter we will deal with the question of the geographical distribution of the *Caulerpa*-species in general. They belong almost exclusively to the true tropical flora, and have their main distribution in the tropical and sub-tropical coasts of the Red Sea, the Indian Ocean, and the Pacific, and also in the tropical Atlantic (to which must be added the Mediterranean), especially the West Indies.

But it must be noted in this connection that the Indian Ocean and the Pacific harbour far more species than the Atlantic. Of the 50 to 60 *Caulerpa*-species known, the majority belong to the ocean area of the Indian and Pacific Oceans, which too is considerably more extensive than the tropical Atlantic (including the Mediterranean), which does not harbour as many *Caulerpa*-species. Many of the species belonging to the former area have a wide distribution, from the Red Sea and the east coast of Africa in the West to the easterly Pacific Islands in the East. Others, however, have a considerably more limited distribution.

Thus, especially southern Australia, including Tasmania, is the home of several characteristic and closely related species forming some very natural groups within the genus, namely, J. G. Agardh's groups, *Hippuroideæ*, *Lycopodioideæ*, *Sedoideæ pedicellatæ*, and *Opuntioideæ*, of which only an occasional species occurs exceptionally beyond the Australian coasts.

Of the species that occur in the tropical Atlantic (and Mediterranean) the majority are common also to the Pacific and Indian Oceans, and there are but half a dozen *Caulerpa*-species at the most that occur exclusively in the Atlantic, whereas the Indian-Pacific Ocean has many (30 to 40) species that do not occur in the tropical Atlantic.

It seems from this that it may be asserted that the genus *Caulerpa*, at least at the present time, has its main distribution within the Indian-Pacific Ocean area.

Very remarkable is the distribution of the species, reaching a number of about 12, which the tropical Atlantic has in common with the Indian-Pacific Ocean. Of the *Caulerpa*-species occurring in Ceylon the following also occur in the West Indies :—

C. verticillata
C. crassifolia
C. taxifolia
C. sertularioides
C. Freycinetii
C. cupressoides
C. clavifera
C. uvifera
C. lætevirens
C. Chemnitzia
C. sedoides

i.e., about half the number of the sum total of the Ceylon *Caulerpa*-species. These are entirely lacking along the southern coasts of South America, which, of course, fall in part outside the tropical zone, and in general do not harbour any *Caulerpa* at all. The flora of the Cape is also very poor in Caulerpas; only five are known, and among the species common to the Atlantic and Pacific only two, *clavifera* and *Chemnitzia*, are included in this number and they are, moreover, *exclusively* found in Natal and on the east side of South Africa, which is washed by the warm Mozambique stream, but not on the west side, which has a much less tropical character owing to cold antarctic currents. It is, therefore, a remarkable fact that the centres of distribution which the species have in common, the Atlantic Ocean on the one hand, and the Indian-Pacific Ocean on the other, are at the present time separated from each other, so that there is no communication between the two different districts for the different species. MURRAY, who has closely studied the problem of the distribution of the tropical algae, has pointed this out with reference to all the marine flora that the Atlantic and the Indian Oceans have much in common. To explain this fact MURRAY has suggested that the two rather similar tropical floras in the Atlantic and the Indian Oceans, which now communicate only *viâ* the Cape, must probably "have been periodically mingled at the epochs of warmer climate at the Cape."

This is perhaps not beyond the bounds of possibility, but it seems to me not improbable that the resemblance between the flora districts of the tropical Atlantic and of the Pacific-Indian Ocean may be explained naturally in another way, namely, that it (the resemblance) must be regarded in combination with the geological data which argue in favour of a pre-historic direct communication between the Pacific and the Atlantic, either across the Isthmus of Panama or further south. That such a communication existed even as late as in the Tertiary Age is beyond all doubt (Compare P. M. DUNCAN "On the Fossil Corals of the West Indian Islands"; R.T. HILL, "The Geological History of the Isthmus of Panama and portions of Costa Rica"; A.E.ORTMANN, "Tertiary Invertebrates"), though opinions differ when the question arises *where* the communication took place, some geologists assuming a more southerly connection than across the Isthmus of Panama.

It is very remarkable that the tropical algal district in the Atlantic is almost confined to the West Indies. This probably depends on the eastern coast of South America, just as the western coast of Africa—as MURRAY points out, not offering suitable habitats for algal growth. But then one can scarcely assume that, even if warmer water washed the south coasts of South America and especially of Africa, a more luxuriant algal vegetation should have been harboured then than is the case to-day, seeing how little suited they are said to be for algal growths of any kind. I therefore think that the communication and the relationship between the floral districts of the Indian-Pacific Ocean and the West Indies can be more naturally explained in another way, *i. e.*, that these districts once had direct communication over the districts where now the Central or South American continent separates the two great oceans.

If we examine the geographical distribution of other marine organisms, we cannot fail often to notice a greater resemblance between the West Indies and the Indian-Pacific Ocean than between the West Indies and the rest of the Atlantic. Let us, for instance, examine the marine phanerogamic plants, to the geographical distribution of which ASCHERSON ("Die geographische Verbreitung der Seegräser") has devoted careful study.

Of the genus *Thalassia* belonging to the family of the *Hydrocharitaceæ* there are only two most closely allied species, viz., *Th. Hemprichii* with uniform distribution from the Red Sea, the Northern Indian Ocean (but not the east coast of Africa, nor the Cape!) to the eastern islands of the Pacific, and *Th. testudinum*, confined to the West Indies alone.

A quite analogous distribution is true of the two closely allied *Cymodocea* species, *C. isoetifolia* and *C. manatorum*, which together form the group *Phycoschœnus*, ASCHERS., which is sharply distinct from the other *Cymodocea*-species. The distribution of *C. isoetifolia* almost perfectly coincides with that of *Th. Hemprichii*, that is to say, the Red Sea, the North Indian Ocean, to the eastern islands of the

Pacific, and the distribution of *C. manatorum* coincides with that of *Th. testudinum*, *i.e.* is exclusively confined to the West Indies.

Similar is the distribution of the two *Halodule* species, viz., *H. uninervis* (FORSK.) ASCHERS., in the Indian Pacific Ocean and *H. Wrightii* ASCHERS., in the West Indies. The latter seems to occur also on the west coast of Africa, but not in the south at the Cape. These species are so similar to each other that OSTENFELD ("Flora of Koh Chang," Part V., Hydrocharitaceæ, Lemnaceæ, &c., page 262), who has devoted a comparative study to them, says : "On the whole it is not possible to distinguish the two species when sterile, except using their quite different geographical distribution as criterion."

Also within the genus *Halophila* analogous distribution can be traced. The majority of the *Halophila* species are at home in the Red Sea, Indian Ocean (they do not reach the Cape, however), and the Pacific, and, besides, there occur very closely allied forms in the West Indies, but not from other parts of the Atlantic coasts of South America, nor from the west coast of Africa. OSTENFELD has lately described from the Gulf of Siam (Koh Kahdat) a *H. decipiens* which is so strikingly like the West Indian *H. Baillonis* that he says (*loc. cit.*, p. 261) : "If the geographical distribution was not so quite different I should prefer to regard it as a variety of *H. Baillonis*, but it is not probable to suppose such a connection, as the sea phanerogams generally have very natural and limited areas and *H. Baillonis* is confined to the shores of the West Indian Archipelago."

Ergo : numerous marine species with wide distribution in the Indian and Pacific Oceans, and which are lacking on the east coast of Africa and at the Cape, find their parallel within the West Indies in often closely allied species which are exclusively confined to the West Indies. The marine flora of the West Indies, at least the marine phanerogams and *Caulerpa*, thus show much greater resemblance and affinities to the Pacific and Indian Oceans than to the rest of the Atlantic. That this is the case also with regard to other groups of algae is certain, and I hope to return to this point again.

That the same is the case also within certain groups of the fauna, where relationship is traceable between West Indian and Pacific species, has been pointed out by several investigators (WALLACE).

One is therefore forced to the opinion that the marine flora and fauna of the West Indies, in part at least, is an off-shoot of the Pacific. In the earlier epochs of the Tertiary Age, and at least up to the beginning of the Miocene period, North and South America, as just mentioned, were separated from each other so that the Carribean Sea was only a bay of the Pacific, or a kind of straits between the Pacific and the Atlantic, and not before the transition of the Tertiary Age into the Quaternary Age did the volcanic formations arise which make up the present Isthmus of Panama and which ever since have separated the Atlantic from the Pacific. But since the Carribean Sea was at relatively so late a period no more than a bay of the great unbroken ocean which is formed by the Indian Ocean and the Pacific, what is then more natural than that this part of the Atlantic should still often show resemblances to the Pacific more than to the rest of the Atlantic. And that such a primitive and old group of plants as *Caulerpa* already then had species that still survive, is highly probable ; since other tertiary organisms are, as far as their species go, very closely allied to or the same as still existing species. And that also such a primitive group as the sea phanegorams in the West Indies and in the Pacific and Indian Oceans should be represented by species that are very closely allied, if not quite identical, follows then as a matter of course. That the species are not quite identical, perhaps only shows that they, after being isolated, have undergone somewhat different evolution, which however has not led them very far apart. This is best shown by this, that among the species in common there are no less than two genera (*Thalassia*, *Halodule*) and one very characteristic sub-genus (*Phycoschœnus* of *Cymodocea*), all of which consist of only two species, of which one is exclusively confined to the West Indies, the other to the Indian-Pacific Ocean.

By assuming that the similarities between the algal floræ of the West Indies and Pacific and Indian Oceans depend on a former direct connection across the present American belt of land, a number of peculiarities in the distribution of some algæ can be explained which cannot be explained by the

hypothesis of a connection by way of the Cape. Thus there are several *Caulerpa* species which the West Indies and the Pacific-Indian Ocean have in common that do not occur farther west than Ceylon and the peninsula of India. Such are *C. verticillata*, *taxifolia*, and *cupressoides*, and to these could also be added one species which is only known from the West Indies and the Pacific, but not from the Indian Ocean, viz., *C. fastigiata*. These species have, therefore, a distribution which in the West does not reach the east coast of Africa, but have, on the other hand, a more eastern centre of distribution in the Pacific. To suppose that these species too, could possibly have come by way of the Cape to reach the West Indies, or *vice versa*, seems unreasonable, for in that case they could scarcely have failed to leave traces in Africa, whereas their distribution is very naturally explained by the supposition of a connection between the Atlantic and Pacific across Central America.

I therefore consider it much more probable that the explanation of the resemblances pointed out by MURRAY between the algæ of the West Indies and those of the Indian Pacific Oceans, must be looked for rather in the historical development of the connection of land between North and South America, which shows that the whole Carribean Sea was once only a bay of the Pacific, than in the assumption that it depends on a connection *viâ* the Cape in a time when the external conditions for tropical algæ were more favourable there than to-day.

For a definitive proof of the above a more detailed comparative investigation of the whole algal vegetation must, of course, be undertaken, and I hope to be able to return to this matter before long.

For the present I will content myself with pointing out that the geographical distribution of *Caulerpa* as well as that of the marine phanerogams, clearly indicates that the relation of the marine flora of the West Indies to that of the Pacific-Indian Ocean must not be determined without taking into consideration the geological history of the connecting link of land between the two Americas.

VI.—LIST OF THE SPECIES.

1.—**CAULERPA VERTICILLATA**, J. G. AGARDH.

J. G. AGARDH, Till Algernes Systematik, I., p. 6.
A. WEBER v. BOSSE, Monographie des Caulerpes, p. 267.
SYN. *Stephanocoelium verticillatum*, KÜTZ.
MURRAY, Catalogue of Ceylon Algæ in the Herbarium of the British Museum, p. 38.
EXSICC.: WITTROCK et NORDSTEDT, Algæ exsiccatae, No. 347!
FERGUSON, Ceylon Algæ, No. 233 and 425!

This plant occurs at Galle in a small but clearly defined district where it constitutes almost the whole of the vegetation. It grows at Galle exclusively around the mouth of the stream or canal that enters the sea at Victoria Park to the north of the town proper. The low rocks, which are here quite covered by sand and mud formed by the stream are entirely coated with *C. verticillata* together with a little *Ceramiaceæ*, and these form the bulk of the vegetation. However, *C. verticillata* did not grow higher than up to the low-water mark, so that it was never exposed at low-water.

Structure of the shoots.—As Professor REINKE in his work on Caulerpa (page 7), in describing this species, confesses that he has been unable to confirm the statement to be found in the literature of the subject, viz., that it has a horizontal rhizome, we may here briefly describe the structure of its shoots and its manner of growth (fig. 1).

It always grows in thick tufts, surrounded by sand, out of which the green tufts stick up so high that they are fully exposed and wave to and fro in the swell. If we examine such a vertical assimilating branch, we shall find that it is rather richly ramified below the sand, and consists of up

growing axes which all grow out of a more or less pronounced horizontal stem (fig. 1 *a*). Horizontal axes occasionally start higher up the vertical branch (fig. 1 *b*). Both the horizontal and the vertical axes bear roots, round which grains of sand are very firmly fastened, so that they do not come away even if violently shaken in water. With careful manipulation we can observe down in the sand remains of "assimilators" (in REINKE's terminology), that have evidently been sanded over. As, moreover, the older horizontal axes often grow quite deep, this characteristic reminds us to some extent of many dune grasses, which when covered with sand form their regenerating shoots from axes higher up the stem, by which means the plant continues to keep on the surface of the sand. The danger of over-sanding may be very great sometimes for *C. verticillata* in its home at Galle, since after heavy showers masses of sand and earth are carried out to sea from the stream, so that the water becomes quite muddy. The subterranean system seems to resemble the rhizomes of the higher plants in that it functions as a store for reserve-material, for its basal branches and axes are quite filled up with starch. The grains of starch, which are comparatively few in the assimilating branches, increase in the lower axes and in the horizontal rhizomes, and are so numerous there that the rhizomes are stained quite dark blue by iodine. They probably function as stores during the plant's resting-time, for in *C. verticillata* there are clear indications of periodicity.

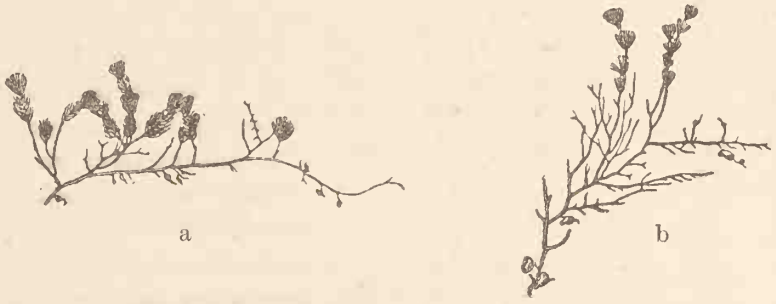

Fig. 1.—*C. verticillata*, J. G. AG. (1 × 1).

Periodicity.—From notes taken by me it seems that *C. verticillata* at Galle reaches its highest development during the months from November to March, when it occurs in masses at the mouth of the river. On visiting the identical spot in August of the same year (1903) it was scantier, but *Ceramia* and other Floridcae were more abundant. The specimens of this plant collected by Prof. KJELLMAN (WITTROCK & NORDSTEDT, Algæ exsicc. No. 347) at Galle during the expedition of the "Vega" also date from December.

Geographical Distribution.—CEYLON: Galle! Colombo (FERGUSON No. 233, 22-1-1871); THE EAST INDIES: (Tuticorin, FERGUSON No. 425) to the Friendly Islands (HARVEY); THE WEST INDIES, in several places.

2.—**CAULERPA SCALPELLIFORMIS** (R. BROWN) WEBER v. BOSSE.

WEBER v. BOSSE, Monographie des Caulerpes, p. 286.
MURRAY, Catalogue, p. 38
f. intermedia, WEBER v. BOSSE.
f. denticulata (DECAISNE) WEBER v. BOSSE.
EXSICC.: FERGUSON, Ceylon Algæ No. 411!

Only observed once locally in shallow water on the projecting spit of land on the west side of Paumben Pass (3-4-03) together with quantities of *Codium* and *Chrysymenia*. I have not seen it anywhere else in Ceylon.

It is, in general, an extremely large *Caulerpa* with leaves attaining as much as 36 cm. in length, but with an average of about 20 cm. The lobes vary considerably in shape, being now quite narrow

and scarcely dentated and curving upwards, now short and broad, clearly dentated, but not curved. Such different forms of lobes occur both on different leaves from the same rhizome and also on *the same leaf*. Of forms that have already been described the main mass of my material resembles most closely the *v. intermedia*, WEBER v. BOSSE, especially the specimens from the Mauritius (according to specimens in AGARDH'S Herbarium in Lund, No. 16,431) sketched by WEBER v. BOSSE ("Monographie des Caulerpes," Pl. XXIII, Fig. 7). In Ceylon there are, therefore, transition-forms between *f. intermedia* and *f. denticulata*, but on the other hand I have never seen *f. typica*, WEBER v. BOSSE (*C. scalpelliformis*, J. G. AGARDH), a characteristic type that seems to be confined exclusively to Australia.

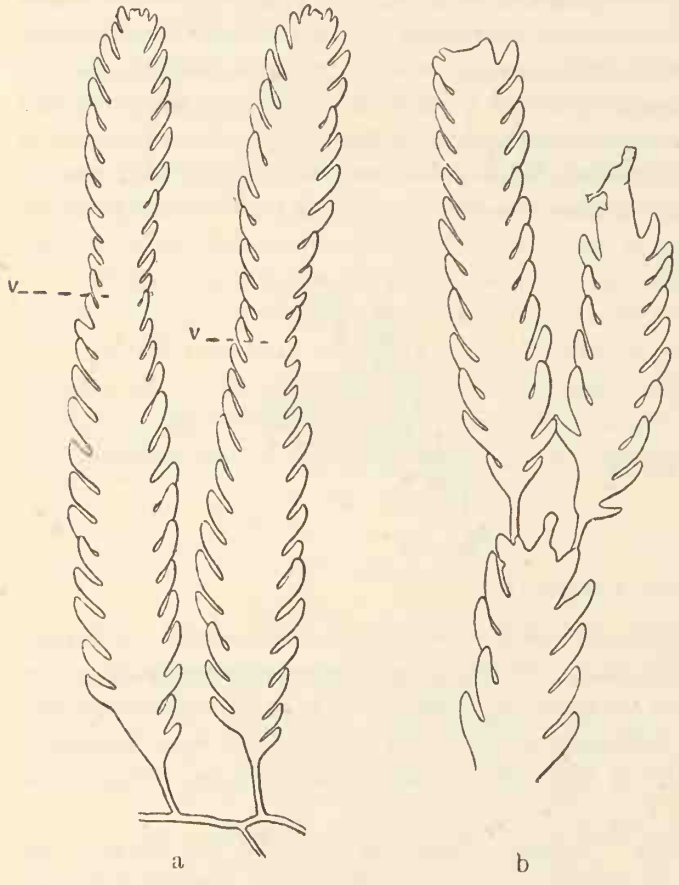

Fig. 2.—*C. scalpelliformis* (R. BR.) W. V. B. (1 × 1).

Structure of the shoots.—Especially characteristic of this species is the rich formation of regenerating shoots, precisely as J. G. AGARDH (Till Algernes Systematik I., p. 13) has asserted of it. These arise either from the points of the lobes, or from the median part of the lamina. Fig. 2 *b* shows an example of this kind of regeneration. But the leaves could increase in another way too without there being any sharp difference in the shape of a petiole. It seems to be such kind of regeneration to which J. G. AGARDH refers when in the description of his *C. scalpelliformis* (*loc. cit.* p. 13) he says: "Frondes saepe quasi innovatione prolongatae, lobis in una parte innovationis brevioribus, dein iterum longioribus," and a very fine example of this can be seen in a *C. scalpelliformis* (Herb. J. G. AGARDH, No. 16,425) collected by HARVEY in Australia. Another case can be seen in fig. 2 *a*. The terminal point of growth of the leaf (once situated at *v*) has after a short period of inactivity, resumed its activity, whereby the leaf has grown longer. This shows itself most clearly in the fact that the leaf has increased in breadth, so that the newly formed basal part has become broader than the upper part of the older portion of the leaf. (An example of the same kind is afforded by HARVEY'S Plate XVII. in "Phyc. Australia" I.)

A proliferation has consequently taken place without the previous formation of a petiole. The leaves of Caulerpa show, therefore, examples of a continued and repeated apical-growth which is unknown in leaves of higher plants, but on the other hand is known in leaves of ferns and lower plants. This goes to prove the predominant shoot-nature of the assimilators, even if they have a shape analogous with leaves. This apical growth, although rhythmical, seems to be rather undefined. From this it is easily explained why the leaves in this species can attain such a great length, greater than in any other *Caulerpa ;* and it is such long growing forms that make up the *f. intermedia.*

If we examine such a leaf more exactly, we shall always find that it shows regularly alternating narrower and thicker parts, due to its development having gone on rhythmically, while the growing point has not worked uniformly, but periods of relative rest have followed periods of more active increase :

consequently a kind of pronounced periodicity in development. The same seems to me to be clear from WEBER v. BOSSE's drawings, (*loc. cit.*, Pl. XXIII., fig. 2, 5, 7).

Fg. 3. *C. scalpelliformis* (R. BR.) W. V. B. (1 × 1).

This unlimited increase in length appears to be more characteristic of *f. intermedia* than of *f. denticulata* (WEBER v. BOSSE, *loc. cit.* Pl. XXIII.), which, even if not always, has yet frequently shorter leaves which are not so strongly proliferate.

Although in general the internal construction of the Caulerpas is not dealt with in this paper, I cannot refrain from touching on the arrangement of the protoplasm strings and of the chloroplasts, so characteristic of this species, as shown in fig. 3. The same has already been pointed out by JANSE ("Die Beweg. d. Protopl. v. C. prol." p. 190) in connection with the description of the same phenomenon in *Caulerpa prolifera*. Numerous main veins run through the centre of the leaf, and from them fan-shaped veinlets run into the lobes, but curve back again toward the main veins, and hence arises the characteristic structure which is shown in fig. 3. It is specially chacteristic of *C. scalpelliformis*.

Geographical distribution.—INDIA : Paumben ! (*f. intermedia* and *f. denticulata*), Tuticorin (FERGUSON, No. 411) ; the Pearl banks in the Gulf of Mannar (Dr. HERDMAN in E. S. BARTON'S, " List of Marine Algæ collected at Ceylon in 1902.") From the RED SEA to the INDIAN OCEAN (Mauritius—Australia—Tasmania) ; ATLANTIC (Angola on the West coast of Africa according to several specimens in J. G. AGARDH'S Herbarium in Lund ! Brazil, according to MURRAY'S " Catalogue of Ceylon Algæ," p. 38).

3.—**CAULERPA CRASSIFOLIA** (AGARDH) J. G. AGARDH.

J. G. AGARDH, Till Algernes Systematik I., p. 13.
M. A. HOWE, Phycological Studies II., p. 574.
SYN. *Caulerpa pinnata*, WEBER v. BOSSE, Monographie des Caulerpes, p. 289.
Caulerpa Harveyana KUTZING, Tab. Phyc. VII. : 5, III.
Caulerpa mexicana SOND. in MURRAY, Catalogue p. 38.
EXSICC : FERGUSON, Ceylon Algæ Nos. 154, 337, 412 !

By examining the original type specimen of the younger LINNAEUS' *Fucus pinnatus* in the herbarium of the Linnaean Society in London, HOWE has shown that this plant belongs to the group Sedoideae and consequently has nothing to do with the *C. taxifolia* (VAHL) *v. crassifolia* AGARDH, which is the type for J. G. AGARDH'S *C. crassifolia* created by him as a distinct species in " Till Alg. Syst." 1, p. 13. I have had an opportunity of examining the specimens HOWE mentions in his paper (*loc. cit.* p. 575), and which are to be considered as the type specimens for *crassifolia*. They are Nos. 16,445 and 16,446 in J. G. AGARDH'S herbarium in Lund, and the specimens of this species that I have collected in Ceylon are quite identical with these, the original specimens from the West Indies. The same is the case with the specimens collected by FERGUSON (Ceylon Algæ, Nos. 337, 154, 412), which are kept in the Peradeniya herbarium under several different names, such as *C. taxifolia* AG. (C. A. 412), *C. mexicana* SOND. (C. A. 154), and *C. crassifolia v. Harveyana* (KG.) GRUNOW (C. A. 337).

There is no doubt left that this plant occurs both in the Indian and the Atlantic Oceans as WEBER v. BOSSE (*loc. cit.* 291) mentions, even if C. AGARDH'S note " In mari Indico & rubro," as HOWE has shown, depends on faulty identification of the younger LINNAEUS' *Fucus pinnatus*. It is worthy of remark that in the AGARDH herbarium itself there are, of *C. crassifolia*, only specimens from the Atlantic but none from the Red Sea, nor from the Indian or the Pacific Oceans.

C. crassifolia occurs in Ceylon rarely in the littoral zone. Thus I have only found it at Weligama (9-3-03) inside the little reef at a depth of 1½m., where the water was very thick with sand. On the

other hand, it seems much more common on the Pearl Banks in the Gulf of Mannar. Thence come fine large specimens from North Moderagam Paar (Gulf of Mannar, leg. JAS. HORNELL, 3-4-03) from a depth of about 10m. (sandy bottom with *Halophila*).

C. crassifolia from Ceylon is, in respect to the increase of the leaf, defined (even if sometimes, though rather exceptionally, a repeated point growth may be observed) as is typically the case in *C. scalpelliformis*.

That such a pronounced growth can occur in *C. crassifolia*, however, is shown by specimens of the species collected by LENORMAND in Venezuela (Herbarium in the Royal Riks-Museum of Stockholm as well as by several specimens in the AGARDH herbarium in Lund. *e.g.* Nos. 16,457–16,460) : from the creeping horizontal axis rise several assimilators and these have very clear proliferations ; the growing point is, as it were, continued in a petiole which supports a new leaf, or, again, the formation of a petiole is wanting, and only the size of the lobes is diminished, to increase again later on. By this means different stories are built up of longer and shorter branches above one another. In passing, mention may be made of the fact that LENORMAND'S specimen also very clearly shows that the point of an assimilator can change its character and grow into a rhizome.

It is impossible for me to distinguish any different forms of *C. crassifolia* in Ceylon. A few specimens have, it is true, somewhat more vertically erected lobes, but they do not seem to have the character even of local forms.

Geographical distribution.—CEYLON : Weligama, at a depth of about 1½m. ! The Pearl Banks in the Gulf of Mannar (at a depth of about 10m.), collected by JAS. HORNELL ! FERGUSON, Ceylon Algæ No. 337! ; Tuticorin, collected by FERGUSON (Ceylon Algæ No. 412)!

RED SEA, INDIAN OCEAN, PACIFIC, ATLANTIC (from the West-Indies to the Canaries).

4.—**CAULERPA TAXIFOLIA** (VAHL) WEBER v. BOSSE.

WEBER v. BOSSE, Monographie des Caulerpes, p. 292.
MURRAY, Catalogue, p. 38.
EXSICC. : FERGUSON, Ceylon Algæ, No. 80 !

f. typica. Pinnules pronouncedly sickle-shaped, curved upwards, 4-5 times as long as the breadth of the main axis.

SYN. *Caulerpa falcata*, KUTZING, Tab. Phyc. VII., 5, v.

f. tristichophylla. Like to the foregoing form, but some of the assimilators have the pinnules at the base clearly arranged in three rows (fig. 5).

f. asplenioides (GREVILLE), WEBER v. BOSSE, *loc. cit.* p. 292 (fig. 4).

f. interrupta. Like the foregoing, but smaller and between the pinnules almost naked parts of the main axis. This variety is formed by repeated rhythmical point-growth of the assimilator (fig. 6).

C. taxifolia occurs on the shores of Ceylon in several forms, which, however, are not sharply distinct, but in places occur mixed together. Most common in the littoral zone is the form described as *f. typica*, illustrated by Kützing under the name of *C. falcata* (" Tab. phyc." VII., 5, v).

But I have also observed *f. asplenoides* GREV. growing together with the main form, especially at Matara in pools filled at low-water. The form *asplenioides* is, in its more pronounced forms (fig. 4). fairly characteristic, with its short, straight, not sickle-shaped pinnules, but transitions into the *f. typica*, are rather common. *F. asplenioides* seems to occur especially in deep water, and this is also the form

that occurs on the pearl-banks on the shells of the pearl-oyster (*Margaritifera valgaris*), where it has been collected by HORNELL (Nov., 1902).

Besides these there occur also some other forms, which, however, are rare, and which do not play any characteristic part in the vegetation. One, which I have called *f. tristichophylla* (fig. 5), I have also observed together with specimens of the *f. typica* at Paumben (3-4-03).

Fig. 4.—*C. taxifolia* (VAHL) W. V. B. *f. asplenioides* (GREV.) W. V. B.(1 ×1).

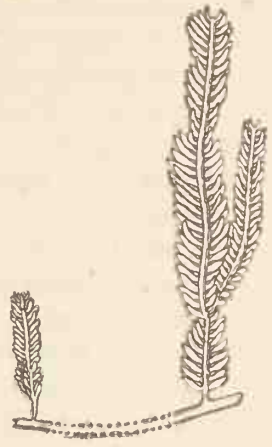

Fig 5.—*C. taxifolia* (VAHL) W.V.B. *f. tristichophylla*, *n.f.* (1 × 1).

From a horizontal axis with a predominant number of assimilators of the main type, shoots forth a branch here and there with a few pinnules in three rows (fig. 5). It is, therefore, closely allied to *C. falcifolia*, and constitutes one of the links between *C. taxifolia* and *C. falcifolia*, as predicted by WEBER v. BOSSE. As *f. tristichophylla* has only a few assimilators with pinnules in three rows and, moreover, only at the base, and as in all other respects it corresponds with *C. taxifolia*, I have come to the opinion that it must be classed under this species, the more as I agree with REINKE in considering that to point out a link of this kind between two otherwise well distinct forms does not necessarily prove that these extreme forms belong to the same species. I am therefore of opinion that in spite of this form one is quite justified in maintaining both *C. taxifolia* and *falcifolia* as different species. Probably they have a common origin. In reality one can observe also in, for instance, HARVEY'S specimen (Friendly Islands Algæ No. 70. Herb. J. G. AGARDH No. 16,522), a few branches with pinnules in only two rows, *i.e.* typical *taxifolia* branches, but for the rest all the others are provided with pinnules in three rows. *C. taxifolia* stands in exactly the same relation to *C. falcifolia* as *C. sertularioides* to *C. selago*. *C. taxifolia f. tristichophylla* is consequently analogous with *C. plumaris f. Farlowii*, WEBER v. BOSSE ("Monographie" p. 295).

Fig. 6. *C. taxifolia* (VAHL) W. V. B. *f. interrupta*, *n. f.* (1 × 1).

As for the *f. interrupta* (fig. 6) it is a little deep-sea form from the pearl banks in the Gulf of Mannar growing together with *f. asplenioides* on the shells of the pearl-oyster. It is a reduced *f. asplenioides* with small, weak branches and small assimilators, with the pinnules in groups on the main axis and branchless parts in between. It is clear that it has originated in a manner analogous with *C. scalpelliformis f. intermedia* : that is to say, that the point growth of the assimilators has gone on rhythmically and hence similar formations have arisen, which can be best compared with proliferations. The form seems to be more occasional, but is, however, of theoretic interest as being a form analogous with similar forms of other species, as for example *C. plumaris f. umbellata*, WEBER v. BOSSE (*loc. cit.*, p. 295).

Geographical distribution.—CEYLON : local and occasional as at Matara ! (*f. typica* ! and *f. asplenioides*!) in rock-pools ; Weligama ! (at a depth of about 2 m. inside the reef together with *Halimeda gracilis*) ; Colombo (*f. typica*, FERGUSON Ceylon Algæ, No. 80 !); Pearl Banks in the Gulf of Mannar ! (*f. asplenioides*

and *f. interrupta* at a depth of about 10 m.), also at Paumben! (South-India) at a depth of about 6 m. (*f. typica*). INDIAN OCEAN. PACIFIC (*f. asplenioides* at Sandwich-Islands). ATLANTIC (the West Indies).

Note that the closely allied *C. falcifolia* has its distribution in the Pacific and on the coasts of Australia.

5.—**CAULERPA SERTULARIOIDES** (GMELIN) HOWE.

HOWE, Phycological Studies II., p. 576.

SYN. *Caulerpa plumaris* (FORSKAL) WEBER v. BOSSE. Monographie des Caulerpes, p. 294.
Caulerpa plumaris, AG. MURRAY, Catalogue p. 38.

EXSICC.: HARVEY, Ceylon Algæ No. 61!; FERGUSON, Ceylon Algæ Nos. 3, 40!; WITTROCK *et* NORDSTEDT, Algæ exsiccatae No. 344!

f. brevipes (J. G. AGARDH).
WEBER v. BOSSE, loc. cit. p. 294.

f. longiseta (J. G. AGARDH).
WEBER v. BOSSE, loc. cit. 295.

f. umbellata (WEBER v. BOSSE)
WEBER v. BOSSE, loc. cit. 295.

Caulerpa sertularioides f. brevipes (fig. 7) is a common littoral form at the surface of the water and seems to prefer spots somewhat exposed, where it grows in company with other green algæ, often in thick tufts (fig. 8). So it occurs on the western, more exposed side of the Galle reef, especially on the flat coral rocks below the Star bastion. On the surface it is often very short and the vertical axes often do not attain more than 1 cm. in height.

Fig. 7.—*C. sertularioides* (GM.) HOWE *f. brevipes*. (J. G. AG.). (1 × 1).

Fig 8.—*C. sertularioides* (GM.) HOWE *f. brevipes* (J. G. AG.). (1 × 1).

The leaves in *C. sertularioides* are often characterized by the same rhythm as I have already described before in several other Caulerpas, *e.g.*, *C. scalpelliformis*, *crassifolia*, and *taxifolia*. The growing point after a period of rest begins a new activity, whereby the first formed pinnules are very short and afterwards increase in size. As now the activity of the growing-point lasts only a very short time and consequently only a small increase in the leaf takes place each time, we thus get the characteristic *f. umbellata* (fig. 9), which is characterized at a hasty glance by its external likeness to *C. verticillata*, in that the branches are arranged in tufts around the main axis. Of course a sharp difference is constituted by the fact that *f. umbellata* has the pinnules predominantly in two directions, in contrast to *C. verticillata*. That *f. umbellata*, however, can also have them in several directions follows from WEBER v. BOSSE's note (*loc. cit.* p. 295).

Fig. 9.—*C. sertularioides* (GM.) HOWE *f. umbellata* (W. v. B.). (1 × 1).

The two forms *f. brevipes* and *f. umbellata* are thus rather closely allied to one another; they grow promiscuously, and from the same *rhizome* there arise also both the one and the other form.

Also *f. longiseta* (fig. 10) characterized by its long, narrow pinnules in close rows, is not uncommon on the shores of Ceylon. But it occurs scarcely ever, if at all, in the upper part of the littoral zone, but usually in somewhat deeper water. It commonly grows, not together with *f. brevipes*, but, as far as I

have observed it, in deeper water, *e.g.*, at Trincomalee at a depth of from 10 to 15 m. It often grows together with *C. taxifolia* as at Weligama, where these two species occurred at a depth of about 1·5–2 m It also occurs at the same place inside cavities in coral stones at a depth of about 3 m.

Fig. 10.—*C. sertularioides* (GM.) HOWE *f. longiseta* J. G. AG. (1 × 1).

Geographical distribution.—CEYLON; in many places; in the upper part of the littoral zone (*f. brevipes* and *f. umbellata*) and also in deeper water (*f. longiseta*) : Tangalla (*f. brevipes*) ! Weligama (*f. longiseta*) ! Galle (*f. brevipes*, *f. umbellata* and f. *longiseta* [KJELLMAN in WITTR. et NORDST. Alg. exsicc. No. 344]) ! Colombo (FERGUSON, Ceylon Algæ Nos. 3, 40! in *Herb.* J. G. AGARDH No. 16,474 (*f. umbellata* and Nos. 16472, 16473, *f. longiseta*); Jaffna (*f. brevipes* and *f. umbellata*) ! Trincomalee (*f. longiseta*) !

RED SEA, INDIAN OCEAN, PACIFIC (to the Friendly Islands), ATLANTIC (from the West Indies to Cape Verde).

6.—**CAULERPA FREYCINETII,** C. AGARDH.

f. lata, WEBER v. BOSSE, Monographie des Caulerpes, p. 313.

I have observed this *Caulerpa* only once, namely, on the south beach of the island of Mandaitivu outside Jaffna in the north of Ceylon, at a depth of about half a metre at low water. It is a pronounced sand form, which has a strongly and well-developed rhizome creeping in the sand with short coarse assimilators. These are spirally bent with branches entangled, forming as it were small matted balls that stick up out of the sand. *C. Freycinetii* is very rich in forms and has an extensive distribution. *f. lata* occurs in the Red Sea, in the Gulf of Siam, and the Indian Archipelago as far as the Marian Islands and the Friendly Islands. REINKE mentions that *C. Freycinetii* occurs in East India, but does not specify any definite locality. In any case it has not been noted before from Ceylon* where, however, it seems to be a rare and accidental constituent, at least in the littoral flora.

Geographical distribution.—CEYLON : Jaffna (the island Mandaitivu) ! RED SEA, INDIAN OCEAN PACIFIC, ATLANTIC (the West-Indies).

7.—**CAULERPA CUPRESSOIDES** (VAHL) WEBER v. BOSSE.

var. typica, WEBER v. BOSSE, Monographie des Caulerpes, p. 327.

I have found this *Caulerpa* only once in the district investigated, namely in the upper littoral zone at Paumben Pass, where it grew together with *C. longistipitata*, *Chrysymenia sp.* and others. The plant is thus very rare within the Ceylon marine-flora district, in any case in the littoral region at least. WEBER v. BOSSE (*loc. cit.* p. 330) points out that the characteristic for this form (= *var. typica* WEBER v. BOSSE) is the great regularity with which the sub-navicular pinnules are arranged in three rows along the main axis, while at the same time an occasional branch with the pinnules only in two rows is not rare. This *C. cupressoides* from Paumben Pass corresponds exactly with this description and with WEBER v. BOSSE drawings (*lo . cit.* Pl. XXVII, 7 b, 2a, 3, and XXVIII., 1). In general the main branches are three-sided, but of the side branches of the last order an occasional one is two-sided. Moreover it corresponds exactly with the specimens collected by BORGESEN from the West Indies.

Geographical distribution.—SOUTH INDIA : Paumben Pass ! ; INDIAN OCEAN, PACIFIC, ATLANTIC (the West-Indies).

* It is however reported from the Laccadive Islands, Minikoi (GARDINER).

8.—**CAULERPA LESSONII,** Bory.

Bory, Voyage de la "Coquille," Crypt. p. 193. 1828. Atlas, Pl. 22, Fig. 3.

Kutzing, Tab. Phyc. vol. 7, tab. 6.

Syn. *Caulerpa fissidentoides*, Greville, Remarks on some Algæ bel. to the Genus Caulerpa. Ann. and Magazine of Nat. Hist., vol. XII, sec. ser. (1853), p. 3, Pl. II.

Caulerpa Lessonii, J. G. Agardh, Till Alg. Syst. I., p. 24 (1872).

Caulerpa pennata, J. G. Agardh, loc. cit. p. 26 (1872). Type-specimen in Herb. J. G. in Lund. No. 16,624 (= Harvey, Friendly Isl. Alg. No. 68; note! some specimens largely intermixed with *C. sertularioides* [Gmelin] Howe!).

Caulerpa Lessonii Weber v. Bosse, Monographie des Caulerpes, p. 339 (1898).

Caulerpa plumulifera, Weber v. Bosse, loc. cit.

Syn. ? *Caulerpa amicorum*, Harvey, Friendly Island Alg. Nos. 62, 63 (Herbarium J. G. Agardh in Lund. Nos. 16,630, 16,631).

Exsicc. Ferguson, Ceylon Algæ No. 413 (Tuticorin, South India)!

f. typica. The vertical axes more or less branched. The assimilators about 5 mm. in breadth with predominantly two-sided (but sometimes at the base also three-sided) pinnules, often larger than the main axis, which goes up to 2 mm. in breadth (fig. 11).

f. tuticorinensis. The vertical axes repeatedly furcated with the basal parts cylindrical for a good way up and without pinnules. The assimilators of three kinds: the majority not above 2 mm. in breadth, flat, with two-sided pinnules of about the length of half the main axis, others flat, as before, of a breadth of up to 5 mm. with two-sided pinnules somewhat bent upward, rather longer than the main axis, which is 2 mm. in breadth (that is, of the same kind as the *f. typica*), and finally too, though rare, assimilators with cylindrical main axis and only three-sided pinnules (fig. 12).

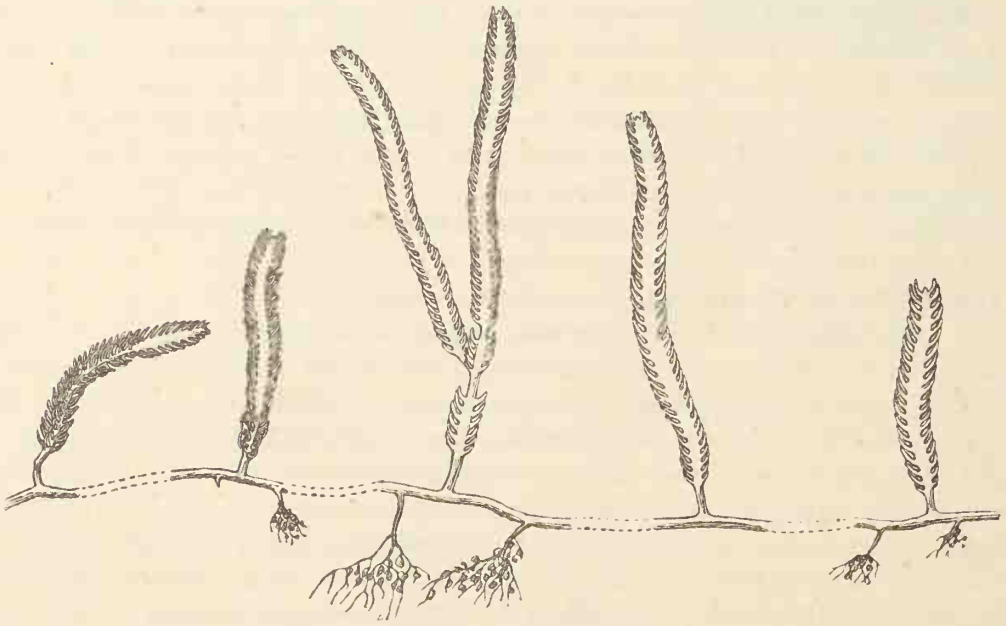

Fig. 11.—*C. Lessonii* Bory *f. typica*. (1 × 1).

The plant designated by me as the main form (fig. 11), was collected in the district by J. Hornell, east of the East Cheval Paar in the Gulf of Mannar, at a depth of about 10 m. It is a sand *Caulerpa* with the same mode of growth as *C. Freycinetii* with a very coarse horizontal stem, which often grows very deep in the sand.

The horizontal stem has very big root-branches which spread themselves in tufts of very fine branchlets, on which particles of sand are affixed very firmly. The basal parts of the assimilators are cylindrical and often without branchlets or pinnules for shorter or longer spaces.

The form *tuticorinensis* (fig. 12) has not been observed by me otherwise than in preserved specimens, and I can say nothing about its mode of growth.

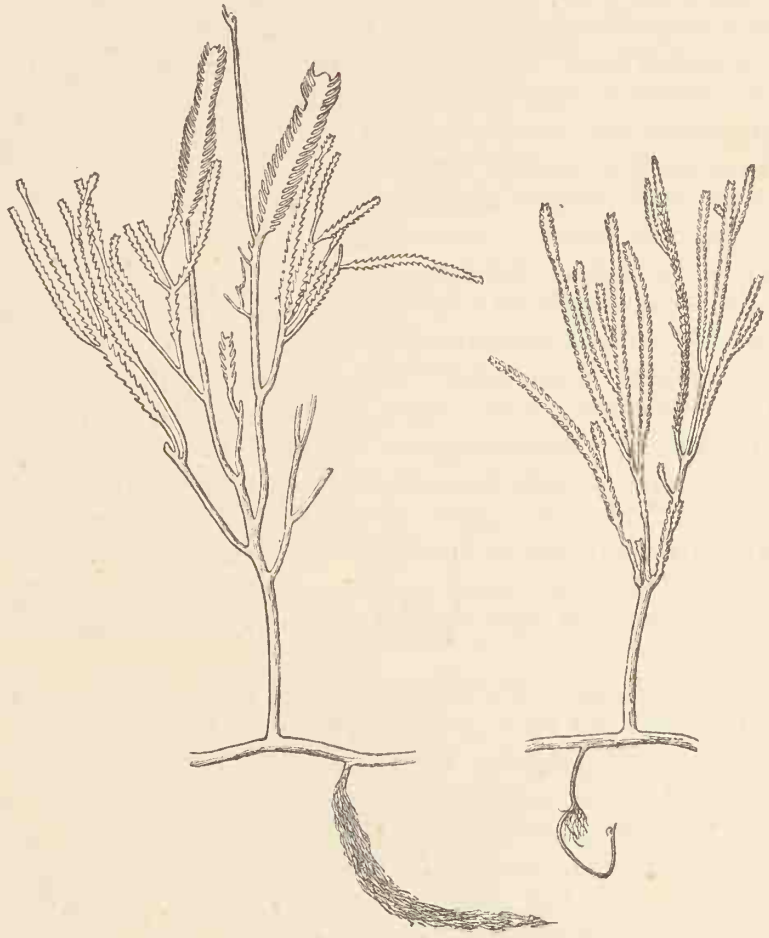

Fig. 12.—*C. Lessonii*, BORY, *f tuticorinensis n. f.* (1 × 1).

Remarks on the species.—Few Caulerpas, one may say, are so variable as those belonging to the group Thuyoideae. Hence, too, the nomenclature of these species is very confused and hard to disentangle. With respect to the species in question it seems to me that the following remark should be made to make clear my opinion about *C. Lessonii* and its synonymy.

The alga that BORY ("Voyage de la Coquille") described under the name of *Caulerpa Lessonii* is characterized by its flat main axis, distinguished by relatively great breadth, with usually two-sided branchlets. Even if, as WEBER v. BOSSE mentions (*loc. cit.* p. 339) BORY'S fig. (or, at least, the copy in Kutzing, "Tab. Phyc." V. T., Tab. 6) has been drawn somewhat too broad, in any case Bory's *Lessonii* must have been characterized by relatively great breadth in comparison with related forms. These latter are to be looked for, on the one side, especially among the *C. cupressoides* series and particularly among var. *lycopodium*, WEBER v. BOSSE, and var. *disticha*, WEBER v. BOSSE; and on the other, also among the *C. Freycinetii* series var *pectinata*. But the main axis in these forms never, in general, approximately reaches the breadth which has been figured in *C. Lessonii*, BORY. Clearly, then, this character must be laid stress on when diagnosing *C. Lessonii*. The fact is that the main axis in this

species reaches as much as 2 mm. in breadth (exclusive of pinnules, of course) and is evidently flat, with two-sided pinnules.

That the plant I have reproduced here from Ceylon (fig. 11), collected by HORNELL on the pearl-banks in the Gulf of Mannar, is identical with GREVILLE'S *fissidentoides* (see GREVILLE, Pl. II., *loc. cit.*) seems to me to be beyond any shadow of doubt. GREVILLE'S figure has the main axis in certain parts almost 2 mm. in breadth, and in my figure (drawn natural size from formalin material) the main axis in many places is fully 2 mm. Also the circumstance that *C. fissidentoides*, GREV., has been collected on "the shores of the Peninsula of India" supports to some extent the assumption that these plants are quite identical. But, on the other hand, this species is, according to WEBER v. BOSSE—who had an opportunity of examining the type specimens—synonymous with *C. Lessonii*. Curiously enough J. G. AGARDH does not mention—as far as I have been able to find—anything about GREVILLE'S *C. fissidentoides*.

If, now, it is quite evident that the alga from the pearl banks is identical with GREVILLE'S *C. fissidentoides* and therefore also with BORY'S *C. Lessonii*, on the other hand the matter is by no means equally evident as far as another alga hereunto belonging is concerned, which has been collected by FERGUSON at Tuticorin in S. India and numbered 413 in his "Ceylon Algæ." It has been determined by GRUNOW as *C. Lessonii*—on the label in the Peradeniya Herbarium one reads "C. pectinata, Kutz"—and it is presumably the very same alga as MURRAY calls *C. fissidentoides* in his "Catalogue of Ceylon Algæ," p. 37. WEBER v. BOSSE, on the other hand, will not accept this determination (cf. "Monographie," pp. 339, 340) but is of the opinion that FERGUSON'S Ceylon Algæ No. 413 is to be referred rather to *C. plumulifera*, ZANARDINI (= *C. pennata*, J. G. AGARDH), at the same time as the author questions whether *C. plumulifera* is not possibly to be coupled with *C. Lessonii*, a matter which can only be settled when fresh specimens have been examined. In the Algal Herbarium in Peradeniya, which was kindly placed at my disposal, there are several specimens of this FERGUSON'S Ceylon Alga 413, but also another one too (FERGUSON, C. A. 161) labelled "*C. fissidentoides*," though of the last-named there is only one very poor specimen, only a few indeterminable fragments.

Where do these forms belong? The first named (C. A. 413) fairly corresponds in the main with WEBER v. BOSSE'S description and figure of *Caulerpa plumulifera*, ZANARDINI (*loc. cit.* p. 340, Pl. XXXI., fig. 3). It is, then, distinguished by assimilators with fairly long cylindrical petioles and with many branches (fig. 12). For the rest, the greater part of the branches also look as in WEBER v. BOSSE'S figure (*loc. cit.* Pl. XXI. fig. 3), which seems to justify this form being referred to *C. plumulifera*. But on a closer examination of the Peradeniya specimens it is soon clear that some are characterized by branches of a quite different kind, viz., partly broad, coarse ones, which by their size and breadth are sharply distinct from the others (the transitions to which are also very abrupt), and partly weak cylindrical ones with three-sided pinnules.

Fig. 12 shows specimens of FERGUSON'S C.A. 413. It is remarkable how the great broad branches absolutely correspond with the character which has been pointed out as characteristic for *Lessonii*. *i.e.* the relative breadth of the axis (up to and above 2 m.m.)and the length of the pinnules. A comparison between these branches and *C. Lessonii* in fig. 11 shows, therefore, a perfect correspondence. But from this it is also the more explicable how GRUNOW has been able to call this Alga *C. Lessonii*, and how MURRAY has included *C. fissidentoides* in his Catalogue of Ceylon Algae. On the other hand, these broad branches are not found in all specimens—*e.g.* not in FERGUSON'S specimens in AGARDH'S Herbarium (Nos. 16614, 16615)—and probably were not in the material that WEBER v. BOSSE had an opportunity of examining—they are not figured in her monograph Pl. XXXI., fig. 3—and from this it is quite natural that she should not have combined this species with *Lessonii*, but rather with *C. plumulifera*, ZANARDINI. But the appearance of the broad branches in the Peradeniya specimens shows, on the other hand, that one is justified in combining it with *Lessonii*, granting it to be a special form, characterized—as so many other *Caulerpa* forms—by some branches showing an appearance that corresponds with one species, other branches with another. As far as the third kind of branches is concerned, they have an appearance that

can be seen from fig. 12. They are narrow, weak, and covered in all their length with small three-sided branchlets or pinnules. By their weakness, and by the fact that they are covered in all their length with three-sided pinnules, these branches differ from those with three three-sided pinnules only at the base in the plant from the pearl-banks. The peculiar transition form which FERGUSON collected at Tuticorin, and which is of great interest owing to the construction of its shoots, I call *f. tuticorinensis*. The nature of this kind of shoots, etc., I have already discussed before in the general part of this work, and I will only emphasize in this place that I am not of opinion that the classification of this form *under Lessonii* as the main species must necessarily be so explained that *f. tuticorinensis* is subordinate to *Lessonii f. typica*. I have only wished in this manner to point out their close genetic relationship.

I think, therefore, that I have shown that BORY's *C. Lessonii*, described and figured as early as 1828, must be retained as at least relatively a well-characterized form. The name *fissidentoides* (GREV.) from the year 1853 must therefore be placed in the list of synonyms. And in my opinion we should also refer *C. pennata* (J. G. AGARDH) from 1872 to the same list. The type-specimens (Herb. J. G. AGARDH No. 16,624) which served AGARDH as the material for his description, are evidently smaller forms of the same species I have figured in fig. 11. Such weaker branches are also to be found among the material of *C. Lessonii* collected by HORNELL. But then AGARDH's *C. pennata* is of the very same coarse structure as *C. Lessonii* and with rather broad main axes. AGARDH, also, in the diagnosis speaks about "rachis atiuscula," just as he says about the plant that is it "robustior." To avoid confusion one must remember that AGARDH's specimens are, as he himself expressly pointed out (Till. Alg. Syst. I., p. 26) mixed with *C. sertularioides* (= *C. plumaris* (FORSK.). It follows as a matter of course that *C. plumulifera*, according to WEBER v. BOSSE's definition, must also be ranged among the synonyms. If ZANARDINI's specimens should also be included is an open question, as I have not had an opportunity of examining ZANARDINI's type-specimens.

That *C. Lessonii* is closely related to *C. cupressoides* is beyond a doubt. Especially the broader forms among the *lycopodium* series are very similar to *C. Lessonii*, and I have been very doubtful about *f. amicorum* in particular, as it offers great resemblance to *Lessonii*. It seems to me not improbable that perhaps several of these forms classed by WEBER v. BOSSE among the comprehensive *C. cupressoides* might with equal reason be transferred to the *Lessonii* group. This may also apply to some *C. Freycinetii v. pectinata* forms. For as WEBER v. BOSSE writes (*loc. cit.* p. 316) about this plant: "Souvent une partie de la fronde, ou des frondes entières, portent de petits ramules opposés, pectinés, *presque aussi grand que ceux du Lessonii.* * Ces échantillons portent dans les livres et la collection de MAZÉ et SCHRAMM les noms erronés de *C. pectinata*, KUTZ. ou de *C. Lessonii*, BORY."

But it is precisely the occurrence of large broad shoot branches with opposite pinnules that seems to refer these forms rather to *Lessonii* than to *Freycinetii*. As for these forms belonging to the Thuyoideae series, it is of more importance that a critical study of them be made in their natural habitat, combined with experimental cultures, and of their geographical distribution, than of perhaps any other Caulerpas, in order to get an insight into the principles governing the variation of these plants, which is necessary as a basis for their taxonomy.

In this connection we may point out that this FERGUSON's C. A. 413, according to notes in the Peradeniya Herbarium, was collected by him at Tuticorin in S. India, and consequently does not really belong to the Ceylon flora. But as all the algæ collected by FERGUSON at Tuticorin have been distributed in the collection "FERGUSON, Ceylon Algae," it is explicable that several forms have been mentioned in literature as being from Ceylon, although, strictly speaking, they have not been found there. For reasons mentioned in my introduction, they are more conveniently dealt with in connection with the Ceylon marine vegetation in general, though not belonging to the flora of Ceylon in a strict politico-geographical sense.

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* Italicised by the present author.

Finally, with regard to the plant named *C. fissidentoides* (FERGUSON, Ceylon Algæ No. 161) in the Peradeniya Herbarium its determination is quite impossible, owing to its insignificance and poor condition. It seems to be closely related to such a form as *C. plumulifera* on Pl. XXXI, fig. 2 (but not fig. 3) in WEBER v. BOSSE's Monograph. On the other hand, it also seems to be very like *C. Freycinetii* var. *pectinata* (Pl. XXVI., fig. 3) and especially the specimens of this form from Koh Kahdat (Gulf of Siam) collected by JOHS. SCHMIDT (No. 108) determined by WEBER v. BOSSE and now in the collections of the Botanical Museum at Copenhagen.

Geographical distribution.—CEYLON : Pearl Banks in the Gulf of Mannar (*f. typica*) collected by J. HORNELL! SOUTH INDIA ; Tuticorin (*f. tuticorinensis*) collected by FERGUSON (Ceylon Algæ No. 413)! INDIAN OCEAN ; PACIFIC OCEAN.

9.—**CAULERPA CLAVIFERA** (TURNER) C. AGARDH.

C. AGARDH, Species Algarum, p. 437.

J. G. AGARDH, Till. Alg. Syst. I., p. 36.

SYN. *C. racemosa v. clavifera*, WEBER v. BOSSE, Monographie des Caulerpes, p. 361.

EXSICC. WITTROCK ET NORDSTEDT, Algæ exsiccatae No.345. FERGUSON, Ceylon Algæ No.17.

f. macrophysa (KÜTZING), WEBER *v.* BOSSE, *loc. cit.*

f. remota. The vertical axes and also the stalks of the branchlets more or less elongated ; the branchlets separated by rather long intervals (fig. 14). This form grows in deeper water.

Caulerpa clavifera is the most common *Caulerpa* in Ceylon. It occurs in somewhat different localities both on rocks and amongst corals, but especially amongst the latter, on both sheltered and more exposed places Amongst corals, on spots with rich supplies of changing water it seems to reach its highest development, and it seems to be one of the very few algæ which can grow together with living corals and Actinians. It grows in rather large tufts (fig. 13) with the horizontal branches creeping amongst the Actinians, and with only the always short vertical axes with their large sparsely scattered spherical branchlets sticking up above them. When it grows directly on stones the roots are rather more numerously arranged as adhesive organs and it becomes a form with a relatively fewer number of coarser branches. Also the vertical axis can attain somewhat different development in different localities. But what is so characteristic of this form is, that the whole assimilation system, *i.e.*, the spherical branches in general, is horizontally spread out in one level. This can be seen best if we look at fig. 13. From the coarse horizontal axis issue these vertical axes, but they are often exceedingly short, so that the spherical branchlets seem almost to be situated directly on them. If, on the other hand. the vertical axes are longer, they frequently come to lie recumbent with the spherical leaves directed only in one direction. A *Caulerpa clavifera* tuft seen from above consequently shows only a mass of small green spheres without any clear arrangement of axis system (fig. 13). It seems to me as if J. G. AGARDH has best drawn attention to this in his description of this plant ("Till. Alg. Syst."I., p. 36) when he says : "Surculi breviores, magis ramosi et intricati quam in plurimis. Frondes erectiusculæ quoque saepe breviores. Hinc ramificatio multo magis irregularis saepius adparet, surculis repentibus, frondibus erectis radicibusque non prope distinguendis, sed in speciminibus exsiccatis quasi sine ordine invicem mixtis." It follows from this

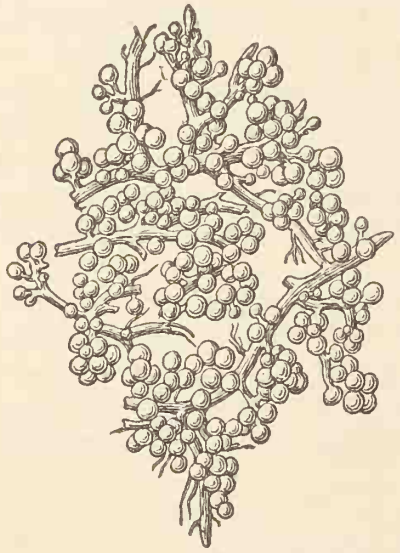

Fig. 13.—*C. clavifera* (TURN.) C. AG. (1 × 1)

manner of growth that this *Caulerpa* in a natural state assumes a very characteristic appearance, which can be gathered from Mrs. PEASE's description of the mode of growth of this plant in Jamaica when she says : (F. S. COLLINS, "The Algæ of Jamaica," p. 237) : "*Caulerpa clavifera* grew like little clusters of green grapes in big raggy masses." TURNER has also succeeded in describing the same characteristic appearance in his "Historia Fucorum" I., p. 126 : "The name of *F. clavifer* has been taken from the appearance of the plant when recent, in which state the branches look as if merely a cluster of small clavate bodies." But the idea of this mode of growth cannot be clearly gathered from even carefully prepared herbarium specimens (cf. for instance WITTR. et NORDST. Alg. Exsicc. No. 345 as 1,204), and this fact has not been sufficiently pointed out in the descriptions.

This *C. clavifera* is a pronounced littoral alga, which is only met with exceptionally in deeper water, and then often under a changed appearance. I have frequently seen it so near high-water mark that at low-water it is only washed by the swell and is thus always fully exposed to almost the whole strength of the tropical sun. And, pressed against the substratum as it is, it might not unappropriately be compared with that type of heath-plants which has been called "espalier plants" (WARMING)—it then receives that strength of light from practically one direction only.

With respect to the size of the spherical branchlets, this varies a little. In general the majority of the forms seem as if they ought to be referred to the *f. macrophysa*, at least acoording to WEBER v. BOSSE's definition of this form in her Monograph (p. 361).

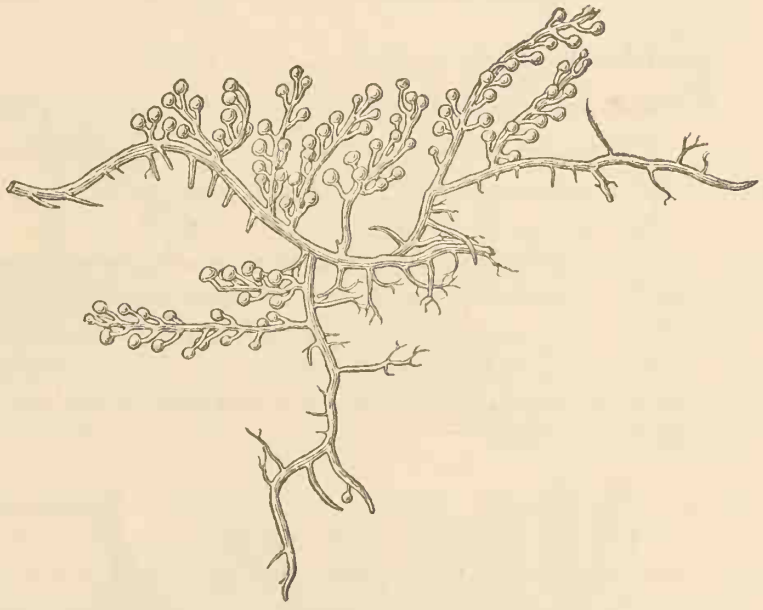

Fig. 14.—*C. clavifera* (TURN.) C. AG. f. *remota n. f.* (1 × 1).

As has been mentioned above, *C. clavifera* forms are, as a rule, never met with in other places than in the uppermost part of the littoral region. Sometimes, however, one can find in deeper water a *Caulerpa* form which apparently is closely related to *clavifera*. Fig. 14 shows such a one, which I found at Galle in a dark deep pool growing on another alga. It differs in that the vertical axis system has been elongated and the branchlets or pinnules have been separated, and especially in that the stalks of the branchlets are often considerably longer than the spherical vesicles, while the main axis itself has been also considerably elongated. The whole plant gets through this, a habit which reminds one of *C. Lamourouxii*, at least its forms which have always cylindrical main axis. The original *f. Lamourouxii*, as it was described by TURNER—and according to him by C. A. and J. G. AGARDH—had only cylindrical axis. But, owing to the occurrence of transition forms to such forms as have flat axis, WEBER v. BOSSE has brought together all these forms under var. *Lamourouxii*, which thereby has received a very extended sense.

Whether such a form as this should be classed under the *Lamourouxii* series, however, seems to me to be very doubtful. There are no transition forms at all from *clavifera* to such ones with flat main axis to be found in Ceylon. This form should, on the contrary, most certainly be derived from *clavifera*, the only closely related form that grows in the district and of which it must be considered as a deeper water or shade form. Naturally it could imaginably be derived from *C. uvifera*, but this *Caulerpa* does not occur at all within the south-west region of Ceylon, but only in the north. Whether it is identical with J. G. AGARDH's *C. racemosa laxa* (Till. Alg. Syst. I p. 35) can only be determined by examining the type-specimens, but there are none in AGARDH's Herbarium. I propose to call this form *f. remota*.

I have not found any periodicity at all in the development of this species; it seems to have the same appearance all the year round.

Geographical distribution.—CEYLON : very common along the coast, but especially on the south-west, more rocky part with coral reefs. Tangalla! Dondra Head! Matara! Weligama! Galle (with *f. remota*)! Ambalangoda! Beruwala! Kosgoda! Jaffna! Kangesanturai! Trincomalee!

RED SEA; INDIAN OCEAN; PACIFIC; ATLANTIC (West-Indies).

10.—**CAULERPA UVIFERA** (TURNER).

SYN. *C. racemosa β. uvifera*, J. G. AGARDH. Till. Algernes Syst. I., p. 35.

C. racemosa var. *uvifera*, WEBER v. BOSSE, Monographie des Caulerpes, p. 362.

F. COMPRESSA, WEBER v. BOSSE, loc. cit. p. 363. EXSICC.: HARVEY, Ceylon Algæ No. 63.

f. intermedia, WEBER v. BOSSE, loc. cit. p. 363.

f. planiuscula. Some branchlets flattened out from above, but between these and the spherical ones regular transition forms are to be found (fig. 16, 17).

SYN. *C. racemosa* var. *uvifera f. intermedia* WEBER v. BOSSE. loc. cit. (pro parte) Fig. 24 a, b, Pl. XXXIII.

What constitutes the main difference between the *clavifera* and the *uvifera* series is that in the latter (fig. 15) the vertical axes (= assimilators, REINKE) reach a higher degree of development, while at the same time they are not so close. They are, as a rule, somewhat longer and have more numerous extremely close branchlets, which are situated around the vertical main axis. The assimilation system does not, therefore, lie on the same level, but each assimilator forms a more limited whole. This probably depends to some extent on the mode of growth.

Fig. 15.—*C. uvifera* (TURNER). (1 × 1).

For, in Ceylon, *C. uvifera* is not to be found in the same places as *C. clavifera*, *i.e.*, in the strictly littoral regions. On the contrary, I have never seen this *C. uvifera* on the coral reefs or rocks in the south-west of Ceylon, where rocks predominate; I have only found it at Jaffna and Kangesanturai in the north of Ceylon from rather deep water and where the shores have quite a different character, with a loose bottom consisting of sand and coral-mud. At Kangesanturai it occurred abundantly, lying free

on the beach, washed ashore probably from somewhat deeper regions. It is also remarkable that in regard to the root-system quite a remarkable difference prevails between *C. racemosa* and *C. uvifera*. The latter has, as can easily be seen by comparing figs. 13, 14, and 15 a much more richly developed root-system.

The root branches are longer and more branched, parting into innumerable fine root-branchlets. These adhere so firmly to sand and shell particles that on uprooting these plants masses of sand and the like will loosen and accompany the roots sooner than these latter break. The *clavifera*, preferably growing on corals and stones, on the other hand, has not by a long way so finely branched a root-system, but is fixed by few and coarser root-branchlets.

The difference that exists between *C. racemosa* and *C. uvifera* in respect to their organization corresponds therefore with different localities. The majority of Ceylon forms of *uvifera* observed by me seem to belong to *f. intermedia* (WEBER v. BOSSE), at least when chief importance is laid on the character which is laid stress on in the diagnosis, viz., that " les ramules " are evidently stalked.

The *f. compressa* WEBER v. BOSSE (HARVEY, Ceylon Algæ 63) I have been unable to find again. On the other hand, in the Peradeniya Herbarium there is a little form from Bentota labelled " *C. sedoides* AG. " which seems identical with Harvey's C.A. 63. Probably it is a mere accidental form, which does not play any very important part in the vegetation.

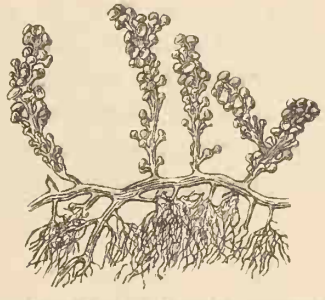

Fig. 16.—*C. uvifera* (TURNER *f. planiuscula n. f.* (1 × 1).

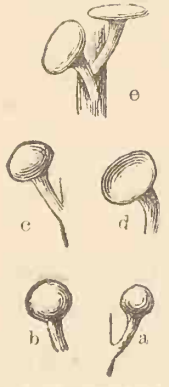

Fig. 17.—*C. uvifera* (TURNER) *f. planiuscula n. f.* Different kinds of branchlets—a, b, c from the base. d, e from the top. (3 × 1).

The *f. planiuscula* is of a great theoretical interest. Fig. 16 shows a picture of it. WEBER v. BOSSE has, in her monograph figured such a form (*loc. cit.* Pl. XXXIII. fig. 24 *a* and *b*.) and also described its origination, though only in the explanatory text accompanying the figure (p. 401, &c), without, however, giving it a special name and only arranging it under *f. intermedia*. She does not mention it in dealing with the different forms of *C. uvifera*. As to the mode of growth and habit, it corresponds with other *uvifera* forms. On a closer examination of the axis, however, we shall find that, especially at the point, flattened out vesicles occur together with transition-stages to the spherical ones (fig. 17). Such branches remind one somewhat of *C. peltata* and *C. Chemnitzia*, but from these the *f. planiuscula* differs partly by the lack of cylindrical branchlets at the base, partly too by the flattened branchlets being more sharply distinguished—the vesicle being more distinctly set of from the stalk and not with the shape characteristic of *Chemnitzia*. The organisation of *f. planiuscula* means, as we can see, a certain increase of the assimilating surface, in analogy with *C. peltata* and *C. Chemnitzia*. But whereas, as for instance in *Chemnitzia*, the flattened branchlets are derived from strictly cylindrical branchlets, in *f. planiuscula* they are formed by transformation of spherical branchlets (cf. fig. 17). These different forms consequently show a fine example of how forms externally similar may be developed in different ways.

Geographical distribution.—CEYLON: *f. intermedia* on the north coast of Ceylon in the deeper parts of the littoral zone; the islands around Jaffna! Kangesanturai! *f. compressa*, Bentota (FERGUSON) and HARVEY (without any more clearly defined locality); *f. planiuscula*, Jaffna!

RED SEA; INDIAN OCEAN; PACIFIC; ATLANTIC (West Indies).

11.—**CAULERPA CORYNEPHORA**, MONTAGNE.

SYN. *C. racemosa* var. *corynephora*, WEBER v. BOSSE, Monographie des Caulerpes, p. 364.

f. complanata (J. G. AGARDH) WEBER v. BOSSE, loc. cit.

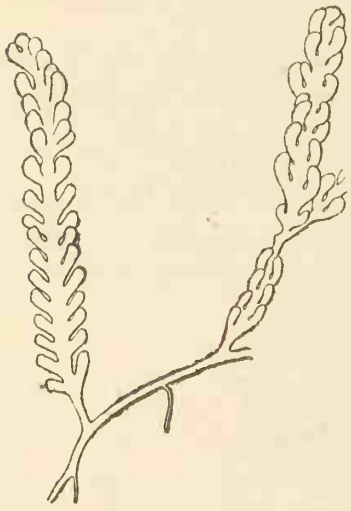

Fig. 18.—*C. corynephora* MONT. *f. complanata* (J.G. AG.) W. V. B. (1 × 1).

In the Herbarium in Peradeniya there is, under the name of "*Caulerpa clavifera* var. ? DICKIE," a *Caulerpa* collected by FERGUSON at Tuticorin (Ceylon Algæ No. 414) on the Indian Coast. As these algæ are in his collection of Ceylon Algæ and as Tuticorin is situated close to the flora district of Ceylon, a mention of this *Caulerpa* form may not be without interest. Fig. 18 shows the appearance of this *Caulerpa*. It has a strongish horizontal rhizome with a vertical axis clearly flat and the branchlets arranged in two opposite rows. It is evident that it belongs to the *corynephora* series in WEBER v. BOSSE's opinion, and corresponds well with J. G. AGARDH'S description of *C. complanata* ("Till. Alg. Syst." I., p. 33), as also with type-specimens in AGARDH'S Herbarium in Lund. We may call special attention to the correspondence with AGARDH'S description of the branchlets (ramenta) as can be seen from the picture. That is to say, they are partly more regular in breadth, partly also constricted at the base, and consequently more clavate at the point. When branches of the latter kind predominate this form has a resemblance to the *Lamourouxii* series, with which the *corynephora* series has evidently some relationship.

Geographical distribution.—SOUTH INDIA: Tuticorin (FERGUSON, Ceylon Algæ, No. 414)! CELEBES; Tropical Coasts of AUSTRALIA.

12.—**CAULERPA LÆTEVIRENS**, MONTAGNE.

SYN. *Caulerpa racemosa* var. *lætevirens*, WEBER v. BOSSE, Monographie des Caulerpes, p. 366.

f. laxa (GREVILLE). WEBER v. BOSSE, loc. cit. p. 367.

GREVILLE, Remarks on some Algæ bel. to the Gen. Caulerpa, Pl. II., figs. 1, 2. Ann. and Magazine of Nat. Hist., vol. XII, sec. ser. (1853).

Caulerpa laxa, GREV. MURRAY, Catalogue p. 38.

EXSICC. HARVEY, Ceylon Algæ No. 64.

f. depauperata. In all respects very slender and weak, smaller than any other forms; it is most nearly allied to *f. laxa*, of which it is probably to be considered a *dwarf* form (fig. 20).

f. cæpitosa. Branchlets swollen up, rigid, cylindrical, or somewhat clavate, the vertical axis short, not above 15 mm. in height and the whole plant firmly and closely tufted with very rigid branchlets rather closely pressed together (figs. 21, 22).

C. laetevirens is perhaps one of the rarest *Caulerpa* forms in Ceylon. I have only observed it at Galle (*f. laxa*, *caespitosa*, and *depauperata*) and Weligama (*f. laxa*) on the south coast, and only at the first-mentioned place in any great quantity, forming a distinct association. At Galle it grows on the ledges north of Victoria Park; there it constitutes by itself almost the whole vegetation in localities strongly exposed to swells, where the slender assimilators swing to and fro in the waves.

In its organization it also shows adaptations to such a mode of life. The rhizome (fig. 19 *a*) or the creeping horizontal axis is relatively strongly developed, and very long, with numerous closely set

root-branches fixed to the scarred rocks ; on the other hand, the vertical axes are few and with rather large intervals between them. The result is that the plant becomes firmly fixed, because the rhizome and the system of roots are so strongly developed in comparison with the relatively few and short assimilation branches which they have to keep attached. The vertical axes are slender with close pinnules. These, in regard to their form, may vary a little, in that they are sometimes quite cylindrical—which is the most common, sometimes more clavate and somewhat flattened laterally. The former kind of branches is the commoner, and if both kinds occur on the same vertical axis the cylindrical ones are to be found at the base, the clavate ones at the top. This form is precisely GREVILLE'S *C. laxa* (HARVEY, Ceylon Algæ No. 64) according to specimens in J. G. AGARDH'S Herbarium in Lund (No. 6,744).

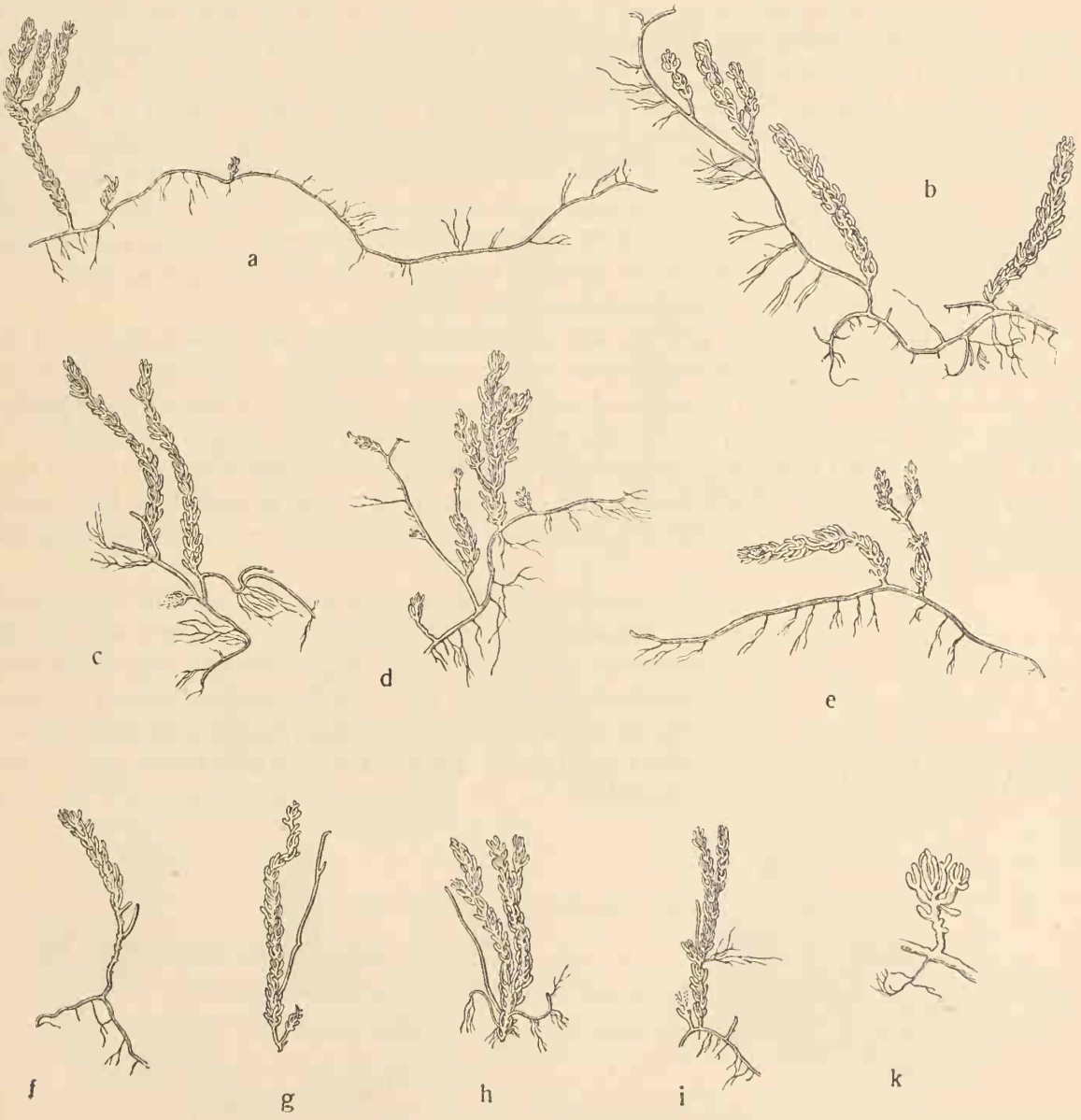

Fig. 19.—*C. lætevirens* (MONT.) *f. laxa* (GREV.); (a—i 1 × 1; k 2 × 1).

As specially characteristic of *forma laxa* and what may also be regarded as a kind of adaptation to its manner of growth in strongly exposed places, is its very strongly developed formation of rhizomes : see fig. 19. In this connection it may be especially pointed out that this form shows great inclination to let the branchlets grow out to horizontal axes which take root and contribute to attach the plant ;

they are consequently a kind of haptera (fig. 19 *a*, *c*, *f*, *g*, *h*, *i*) ; but these branchlets again form vertical axes and behave exactly as the other horizontal axes. The figures show several examples of this : so in fig. 19 *f*. we see a vertical axis where most of the pinnules at the base are gone, and only a few remain, which are just in the stage of growing out. They have not, however, as yet reached any length. Different is the case, on the other hand, with those which are given in fig. 19 *a*, *g*, *h*. In fig. 19 *a*, for instance, may be seen a fully grown branch beginning to branch; in fig. 19 *h*, where, moreover, several branchlets have grown out it has formed roots too; and the same is the case in fig. 19 *i*, &c. In all these cases it has been assimilation branches that have changed character and turned into attaching organs. These changed branchlets might possibly be looked upon as of little value, since they do not develop in the same level as the rest of the rhizome system ; but here we must observe that the rocks are, of course, very uneven, with crevices and cavities, so that the haptera easily grip, even if they are developed higher up. This form with its creeping and climbing rhizomes entangled in each other forms almost mat-like associations, from which here and there rich shoot systems radiate. Of all the Caulerpas I have studied in Ceylon there is none which shows itself in its system of shoots so well adapted for the conditions of life in which it grows as this. That the same seems to be the case with this species in other places, for instance Western Australia, can be gathered from HARVEY's notes ("Phyc. Austr." I., Pl. 30). HARVEY says that the rhizomes form mats of the length of an inch or more with numerous and long roots, an apperance which is also to be seen in his figures of this plant. HARVEY also mentions that it grows "in exposed tide-pools" even if it is not absent in sheltered places.

But the branchlets not only grow out into new rhizomes, but may also directly branch and form new assimilation branches. This is also a rather common case and several examples of it are to be seen in fig. 19 *a*, *d*, *e*, *h*, *i*, *k*. In fig. 19 *d* appears an assimilator where three to four closely set branchlets have grown out in this manner into new assimilators, which are placed as a whorl around the main axis. In fig. 19 *k* is shown, doubly magnified, a young assimilator of which the branchlets have begun to part themselves in several branchlets. In few Caulerpas can the branchlets change so easily both into rhizomes and into new assimilators as in *lætevirens f. laxa*. The branchlets thereby very evidently betray their shoot-nature.

Fig. 20.—*C. lætevirens* (MONT.) *f. depauperata n. f.* (1 × 1).

I have never seem any forms so big that they could be classed under *f. typica*, WEBBER v. BOSSE (*loc. cit.* p. 366), nor have I seen any that could be classed under *f. cylindrica* with any certainty ; practically all are identical with *f. laxa*, GREV. But, on the other hand, one can sometimes find forms as exceedingly stunted as those figured in fig. 20 and which I have called *f. depauperata*. Such dwarf forms may also be seen in other Ceylon Caulerpas.

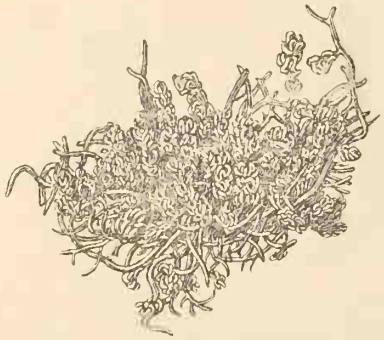

Fig. 21.—*C. lætevinens* (MONT.) *f. cæspitosa n. f.* (1 × 1).

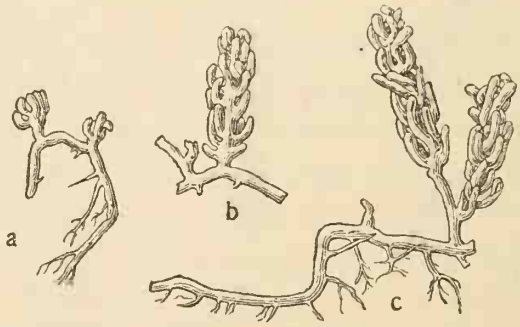

Fig. 22.—*C. lætevirens* (MONT.) *f. cæspitosa n. f.* (2 × 1).

As an ecological form of great interest *f. cæspitosa* (figs. 21, 22) is worth considering. It differs partly by being somewhat smaller and in the form and rigidity of its branches, and partly and

especially in its mode of growth. The vertical axes are very short and closely set. The often flattened branchlets are rather rigid, and turned either up or down, and mostly directed so that as much of the surface as possible is exposed (fig. 22). This is often produced by a torsion of the branch, so that the flat side gets turned upwards. Moreover, the branches sometimes become somewhat enlarged at the point: in any case the result is that a close compact tuft-formation is produced with, at the same time, the exposure of as much of the assimilation-surface as possible. To the rigidity of the tuft-formation contributes, too, the fact that the branchlets are very rigid and not, as in the other forms, easily waved to and fro. This form, so biologically different, was found by me on stones together with several other tuft-forming seaweeds in somewhat deeper water, so that they were not laid bare at low-water and not so strongly exposed to the swell as *f. laxa.*

Finally, it seems to me to be by no means unimportant to point out that the *laxa* forms in Ceylon showed themselves very constant and well defined from other *Caulerpa* forms. In every case transition forms to the *clavifera* and the *uvifera* series were entirely absent.

Geographical ditribution.—Ceylon: Galle (*f. laxa* and *f. depauperata* in exposed places; *f. caespitosa* in somewhat deeper water or not so exposed places)! Weligama! Indian Ocean (Western Australia); Atlantic (West Indies).

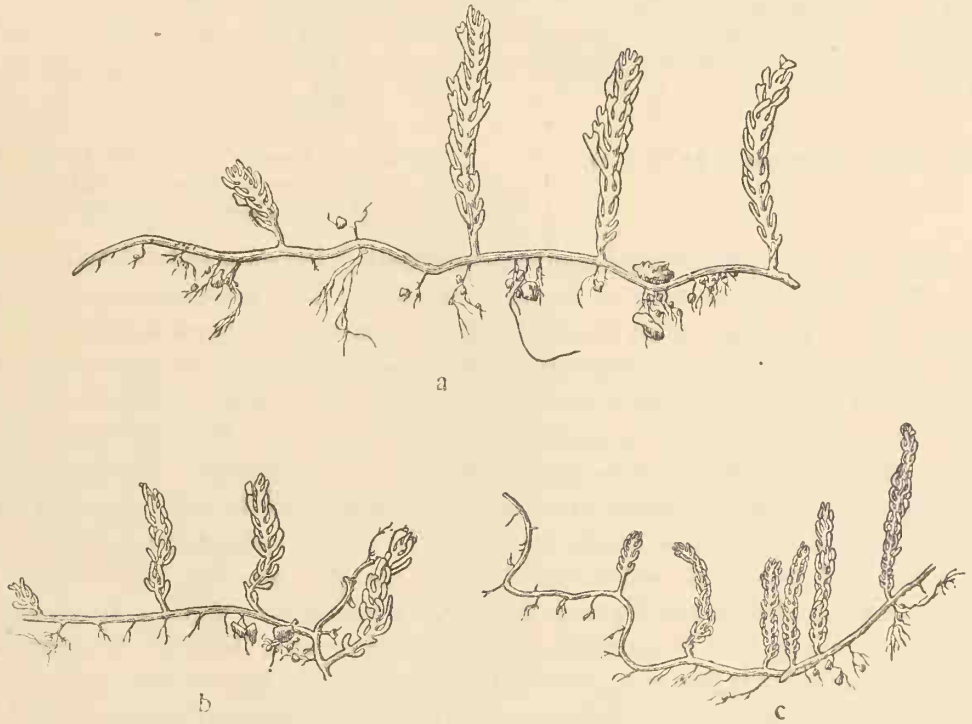

Fig. 23.—*C. dichotoma n. sp.* (1 × 1).

13.—**CAULERPA DICHOTOMA,** n. sp.

The horizontal axis enlarged, creeping, with the upward flattened vertical axis up to 4 cm. in height with generally opposite, always flattened branchlets with generally furcate dichotomous points (figs. 23, 24).

C. dichotoma comes near to *C. lætevirens* and *C. Lamourouxii*, but differs from both in having the greater part of its branchlets dichotomous.

I found this *Caulerpa* at Weligama at a depth of from 1 to 2 m. on sandy bottom.

What justifies its creation as a special elementary species is its characteristic quality of the branchlets being dichotomous (fig. 23). A typically developed axis with such branchlets is to be seen in fig.

24 *a*. In general, the branchlets at the base seem to be undivided (fig. 24), and the dichotomous branchlets only begin higher up. On the other hand, assimilators from the same horizontal axis occur, with both prevalently simple and prevalently dichotomous branchlets

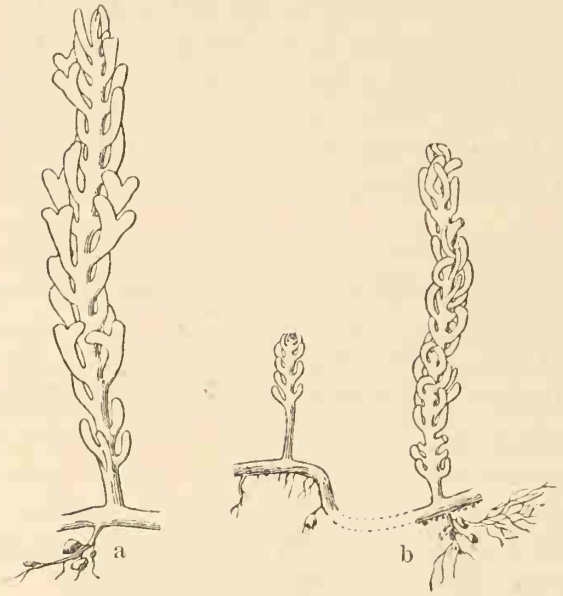

Fig. 24.—*C. dichotoma n. sp.* (2 × 1).

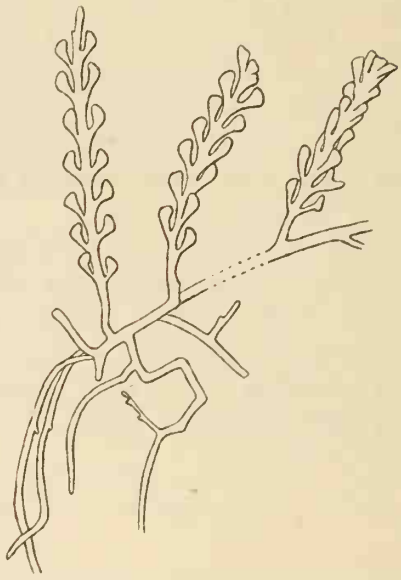

Fig. 25.—*C. Lamourouxii* (TURN.) from Yemen coll. by MONTAGNE. Specimen in the Herb. in the R. Riksmuseum in Stockholm. (1 × 1).

This *Caulerpa* is without any doubt nearly related to both *C. lætevirens* and such types as *corynephora* or *Zeyheri*. The correspondence with *C. lætevirens*, especially the *f. laxa*, shows itself in the simple pinnules, especially at the base, which also in *f. laxa* are somewhat flattened together from the sides. Moreover, the vertical axes are often cylindrical in *C. dichotoma*, in which case also the pinnules radiate from all sides, and this is especially the case at the base. The plant, too, at a first glance gives the impression of a *C. lætevirens*, though the mode of growth is rather different. On the other hand, the flattened axes with their opposite pinnules indicates a close resemblance to *corynephora*. But a new fact is added to this, viz., the tendency of the pinnules to branch dichotomously, and it is this character that justifies the creation of this plant as a special elementary species. A certain resemblance seems to be present to the little weak *f. Zeyheri*, too, which has also the pinnules opposite and laterally flattened; but it is always very slender, and at the same time it has always simple pinnules of somewhat different shape, so that a confusion with *C. dichotoma* is not likely to occur. However, *C. dichotoma* is very similar, or at least analogous in its development to both *lætevirens* and *Lamourouxii* (in WEBER v. BOSSE's definition). In the Herbarium in the R. Riksmuseum in Stockholm there is a *Caulerpa* labelled *C. clavifera* AG. (Yemen) from MONTAGNE's Herbarium. On the same shelf are mounted two distinct forms, not only typical *clavifera*, but also some specimens of another with flat axes and opposite sparse pinnules with the appearance of *C. Lamourouxii* (Pl. XXXII. 1 WEBER v. BOSSE, *loc. cit.*). On one of these (fig. 25) there are a few axes in which some branches show a trace of this very dichotomy which occurs typically in *C. dichotoma*. And on a closer examination of other Caulerpas I also found in the Herbarium in the Copenhagen Museum a Caulerpa on the label of which was only noted that it had been collected in "India orientalis." with similar dichotomous branchlets. It is a rather low, flat *Caulerpa* with sparse single branchlets. One of these is dichotomous. But in none of these latter specimens were the dichotomous branchlets so plentiful as in *dichotoma*. Probably *C. dichotoma* is a form which is closely allied to *lætevirens* and *Lamourouxii*, which two latter are themselves closely allied. But this does not prevent *dichotoma* being distinguished as a special elementary species, and REINKE is undoubtedly right in pointing out that the

discovery of some transition forms between two *Caulerpa* types need not necessarily result in the union of these species.

C. dichotoma has a different mode of growth to *C. lætevirens f. laxa*, for the former does not occur on rocks in very exposed localities, and the latter does. *C. dichotoma* is only to be found on sandy bottoms in somewhat deeper parts of the littoral zone.

Geographical distribution.—CEYLON : Weligama (at a depth of about 1 to 2 m.) !

14.—**CAULERPA CHEMNITZIA** (ESPER) LAMOUROUX.

J. G. AGARDH, Till. Algernes Systematik, I., p. 36.

SYN. *C. racemosa* var. *Chemnitzia*. WEBER v. BOSSE, Monographie des Caulerpes, p. 370.

Few Caulerpas, as far as their definition goes, may be said to be more difficult to diagnose than *C. Chemnitzia*.

It is really indisputable that the opinion—in the main—of the position of this form, as expressed by WEBER v. BOSSE, is right : it is to be considered as a transition form between *C. racemosa* (WEBER v. BOSSE *sens. lat.*) and *C. peltata*. Its distinguishing character is that, as a rule, it has branchlets of different kinds, viz., partly cylindrical ones at the base of the vertical axis, and partly, higher up, such as slowly increase in breadth and are nearly trumpet-shaped. Figs. 26 and 27 show pictures of some which I consider to belong to typical *C. Chemnitzia*.

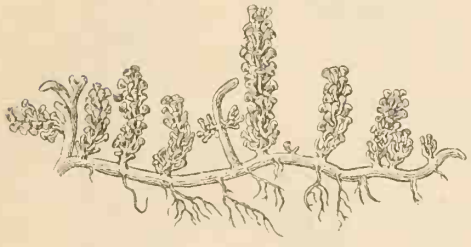

Fig. 26.—*C. Chemnitzia* (ESP.) LAM. (1 × 1).

Fig. 27.—*C. Chemnitzia* (ESP.) LAM. (3 × 1).

Fig. 28.—*C. Chemnitzia* (ESP.) LAM. f. *ad peltatam* (1 × 1).

A closer examination of this species shows, however, that it has not always these types of branchlets but that it varies very considerably, and these variations may point in different directions. One type of variation is to be seen in fig. 28 and fig 29 : the cylindrical basal axes are rather few, but on the other hand the trumpet-shaped axes begin very early, and they constitute the majority of the branchlets, ultimately to change—and it is this that is most noteworthy—into typical *peltata* branches with large discs and a sharp limit between disc and stalk (fig. 28.) Herein we can see a good example of the fact that *C. Chemnitzia* can go over to *C. peltata* and that the supposed relationship between *C. Chemnitzia* and *C. peltata*, as supposed by former authors, *e.g.*, DECAISNE, ZANARDINI, is fully justified.

But, on the other hand, there are also forms which point in quite a different direction. In Ceylon too, there are *C. Chemnitzia* forms which have their upper branchlets developed more in a spherical than a disciform way. Fig. 30 shows such a form growing together with other *C. Chemnitzia* forms. Such are more rare on the Ceylon coast, but occur more frequently on other coasts. Thus ASKENASY ("Forschungreise, S. M. S. Gazelle," IV., Algen) mentions such a form from New Guinea, and BORGESEN has collected a similar one in the West Indies at St. John (WITTR., NORDST. ET LAGERH. Alg. exsicc. No. 1,586) which is very characteristic in that the upper part of the vertical axis to nearly half the length of the axis is provided with spherically swollen branchlets. It is also a typical form of this kind that REINKE gives in fig. 57 of his work on Caulerpa. Such forms seem to be more common in the West Indies and it is apparently such a form that J. G. AGARDH has grouped as *β. occidentalis* in his Caulerpa Monograph,

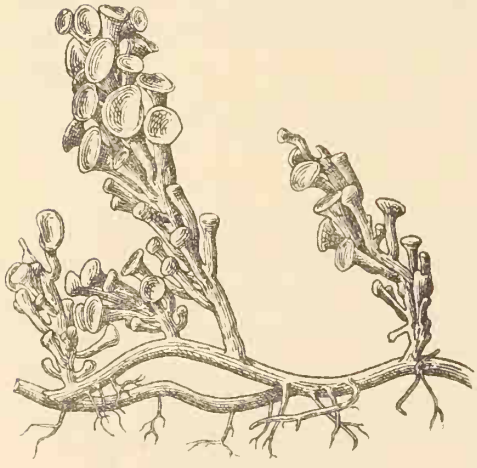

Fig 29.—*C. Chemnitzia* (ESP.) LAM. f. *ad peltatam.* (3 × 1).

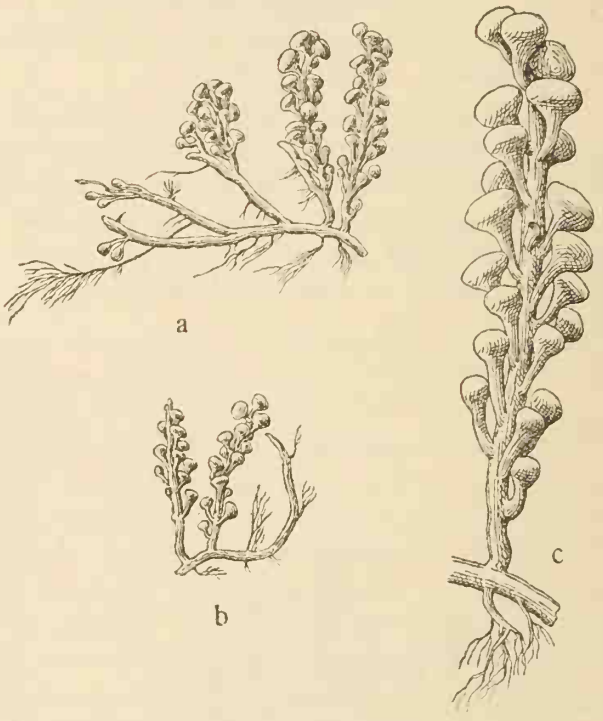

Fig. 30.—*C. Chemnitzia* (ESP.) LAM. f. *ad uviferam.* (a, b 1 × 1 : c 3 × 1).

p. 37. And it is naturally the existence of such forms as has induced WEBER v. BOSSE in her monograph to class *C. Chemnitzia* as a variety of *C. racemosa* (*sens. lat.*) thereby following up an idea suggested first by ASKENASY *loc. cit.* p. 16) even if she lays stress on its transitionary position between "*racemosa*" (*sens. strict.* = *uvifera*) and *peltata*.

But if now *Chemnitzia*, as I have already shown, can develop to the same extent in the *peltata* direction as in the *uvifera* direction, it seems evident to me that it could with equal justification be classed under *peltata* as under *racemosa-uvifera* (*sec.* WEBER v. BOSSE). And judging from the variations of this species in Ceylon, one would be inclined to prefer the latter. But in my opinion both would be equally unhappy. For it is clear that *C. Chemnitzia* should be considered as a more original form than either *uvifera* or *peltata*. In reality it can develop into either. That in both variations the *basal* branchlets, *i.e.*, the first formed and earliest developed, are cylindrical seems to prove that this is an original character. If all the branchlets continue to be of this kind we get *C. lætevirens*, while if some begin to show trumpet-shaped swellings, but with flattened points, we have the typical *Chemnitzia*, which—according as the variation assumes the disciform or the spherical shape—gives rise to *peltata* or *uvifera*, respectively. But it follows from this also that *C. Chemnitzia* is to be placed under neither the one nor the other, but

should be classed as independent, as a special elementary species, and that the others should consequently be subordinated to it as varying in different directions.

Also such a form as *C. imbricata* might be directly attached to *C. Chemnitzia*, *i.e.*, by means of the little *f. mixta* with the cylindrical basal pinnules. But since this lacks the slowly tapering trumpet-shaped branchlets, this is a reason that opposes such a suggestion.

Geographical distribution.—CEYLON : only the North parts : Jaffna! Kangesanturai (from somewhat deeper water) ! SOUTH INDIA : Paumben Pass ! RED SEA ; INDIAN OCEAN ; ATLANTIC (West Indies) ?

15.—**CAULERPA PELTATA**, LAMOUROUX.

J. G. AGARDH, Till. Algernes Systematik, I., p. 37.

SYN. *C. peltata* v. *typica* (pro parte) WEBER v. BOSSE, Monographie des Caulerpes, p. 375.

This species has a characteristic mode of branching and growth (fig. 31). From the rather coarse horizontal axes spring long vertical axes with plenty of peltate branchlets. As the illustrations of this

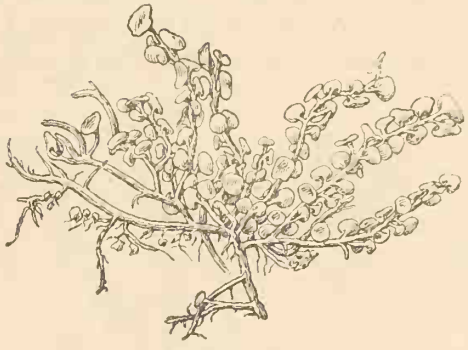

Fig. 31.—*C. peltata* (LAM.). (1 × 1).

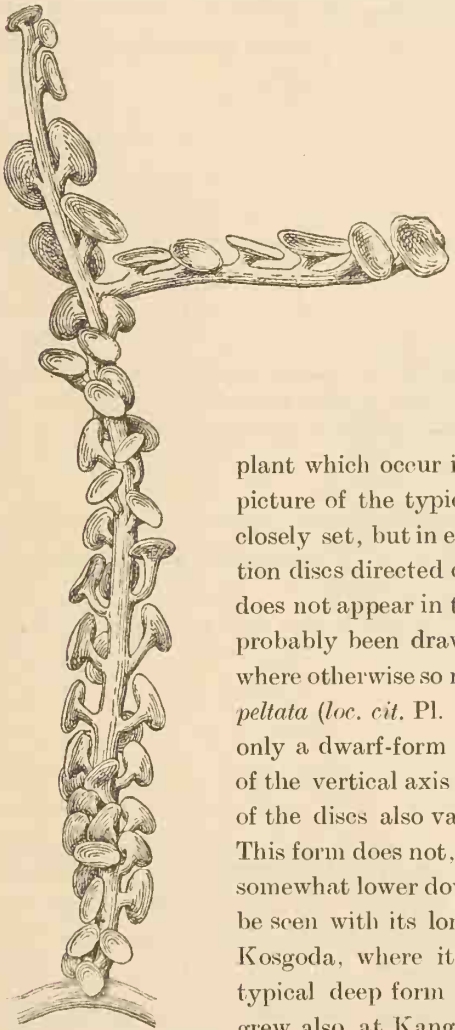

Fig. 32.—*C. peltata* (LAM.) f. *ad nummulariam*. (3 × 1).

plant which occur in literature are rather unsatisfactory, I have in fig. 31 given a picture of the typical *peltata* form. The disc-shaped branchlets are more or less closely set, but in every case they radiate in all directions with the peltate assimilation discs directed obliquely upwards. It is precisely this direction of theirs which does not appear in the figures of this form which occur in literature, and which have probably been drawn from dried material. So in WEBER v. BOSSE'S monograph, where otherwise so many Caulerpas have been excellently reproduced, the figure of *C. peltata* (*loc. cit.* Pl. XXXI. 9) is scarcely happy, and in REINKE'S work on Caulerpa only a dwarf-form with discs pointing in one direction is drawn. The length of the vertical axis naturally varies very much from 1 up to 10 cm. The diameter of the discs also varies, but the average diameter may be said to be about 3 mm. This form does not, as a rule, occur in the uppermost part of the littoral region, but somewhat lower down. It is consequently never exposed at low water, but can then be seen with its long axes swaying to and fro in the swell. This was the case at Kosgoda, where it grew on stones in densely shaded pools together with such a typical deep form as *Dictyurus purpurascens*. In very similar circumstances it grew also at Kangesanturai on the island of Jaffna. At the last-named place I observed a rather remarkable form ; fig. 32 is a picture of it. It is a largely branched, elongated form of which the majority of the branchlets are typical *peltata* branchlets Some of the assimilators, however, are clothed only at the base and a little way up with such branchlets : at the top, on the other hand, branchlets of a different kind are developed, especially on the side axes : the joints become longer between the different branchlets, at the same time as their discs

increase in size. Moreover the side axes have a pronounced tendency to develop their disciform branchlets on one side only, *i.e.*, on the upper side ; which apparently depends on their position in relation to the horizontal level. For, horizontal axes form their assimilation system only on the upper side, vertical ones all round, which is natural from the point of view of their exposure to the light of most advantage to them ; this is especially the case if these horizontal axes take root. A transition to *C. nummularia* is thus effected, since, as I will show later on, it is just this form that is characterized by its assimilation discs being one-sidedly developed on the horizontal procumbent main axis.

Also in another respect this form is remarkable in that, as fig. 33 shows, some of the disciform assimilation branchlets are somewhat swollen and thus would very closely remind one of *clavifera* branches, if a rather evident border did not give evidence of the branchlets having originally been flat (fig. 34). Weber v. Bosse mentions about *C. macrodisca* (Agardh), that its great branchlets are " distinctement bombés dans l'eau pour devenir bientôt plates quand ils en ont été retirés." While then in the case of *C. macrodisca* it seems to be the rule, in *peltata* it is rather the exception, the majority of the branchlets having quite flat assimilation discs. It is to be noted that *C. nummularia*, too, seems to have the same tendency. So Harvey's Friendly Island No. 76 (Herb. J. G. Agardh, 16814), very evidently shows a mixture of *nummularia* and *clavifera* branches. This form Harvey has called *C. clavifera v. platydisca.*

Fig. 33.—*C. peltata* (lam.) f. *ad claviferam* (1 × 1).

Fig. 34.—*C. peltata* (lam.) f. *ad claviferam*, swollen branchlets from the upper part of an axis. (3 × 1).

Geographical distribution.—Ceylon : in the somewhat deeper parts of the littoral zone : Galle ! Kosgoda ! Kangesanturai ! Jaffna ! distribution for the rest uncertain, because of the incompleteness of the notes previously made about it.

I have seen unmistakable specimens of this form from the Red Sea and from the Java Sea (Batavia).

16.—**CAULERPA NUMMULARIA** (Harvey) Reinke.

Reinke, Ueber Calerpa, p. 39.

J. G. Agardh, Till. Algernes Syst. I., p. 38.

Exsicc. : Harvey, Friendly Island Algæ, No. 77.

Ferguson, Ceylon Algæ, No. 101.

Under this name Harvey distributed a Caulerpa from the Friendly Islands (No. 77) which was more exactly described by J. G. Agardh (" Till. Alg. Syst." I., p. 38). As characteristic of this form he accentuated its great assimilation discs which are often crenulate at the border, and from these crenules new stalks and discs grow out. But Agardh also points out that the species is closely allied to *peltata* and that the distinguishing character (*i.e.*, the crenulate discs) is far from being constant, for smooth-edged and crenulate assimilation discs occur together from the same horizontal axis. Weber v. Bosse also accentuates this character as the main character for her var. *nummularia*. Reinke, however, who in his treatment of the Caulerpas has a sharper eye for the morphopogical differences between the types, finds the boundary between *peltata* (main form) and *nummularia* to consist in the mode of branching. He says : Bei *nummularia* fehlen die Axen der Assimilatoren gewöhnlich ganz, so dass die kreisrunden, gestielten Blätter direkt dem Rhizom entspringen" (" Ueber Caulerpa," p. 39). With this Reinke seems,

in my opinion, to have really hit upon the true character of this type. For, if we examine HARVEY'S type-specimen (Friendly Isl. Alg. No. 77, at least the examples which are preserved in the Herbarium in the R. Riksmuseum in Stockholm) we shall find that, in reality, there are very few discs which are crenulate, and not in a single case have I been able to verify that a new stalk grows out from the crenule of the disc. Every time I thought I had found such a case the stalk in reality shot out from the stalk of another disc ; but owing to the pressing it had had, this was not evident, and it seemed to emanate from the crenule itself. On the other hand, it is very characteristic that the side-branches which support

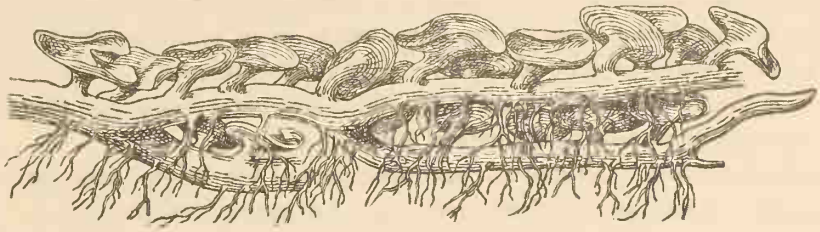

Fig. 35.—*C. nummularia* (HARV.) REINKE. (3 × 1).

the assimilation discs become procumbent and take root ; and the result is naturally a mode of branching as REINKE described it, *i.e.*, the assimilation discs grow directly out from the rhizomes. Fig. 35 shows a picture of *C. nummularia* from the side. From the elongated creeping rhizome emanate numerous side branches and also single branchlets. The former become procumbent and form rows of horizontally placed assimilation discs. The branch formation may be so plentiful and the assimilation discs so numerous and close that such a tuft, seen from above, only shows the shape of a mass of assimilation discs without

Fig. 36.—*C. nummularia* (HARV.) REINKE. (1 × 1).

apparent order, crowded about each other (fig. 36). This results from *nummularia*, in the same way as *C. clavifera*, being a pronounced light alga, and so belonging to the uppermost parts of the littoral zone just as in *clavifera* its whole assimilation system is horizontally broadened out in one level. Hence the tuft formation is distinctly carpet-like.

Undoubtedly this form is derived, as perhaps an ecological race, from *peltata* (main form), and the transition forms which I have already described show this very evidently ; the horizontal axes in the form from Kangesanturai (fig. 32) have precisely the mode of branching characteristic of *nummularia*. To what extent light directly affects the formation of these forms, I do not venture to decide. But to judge from the difference between the intense light in the upper littoral zone, where *C. clavifera* and *C. nummularia* occur, and which, at low water especially, when they are nearly uncovered, is naturally of great strength compared with the shading that takes place in the deeper localities where *C. uvifera* and *C. peltata* occur, one is tempted to presume that this mode of growth depends to a certain extent on the light. Experiments alone can decide this point satisfactorily.

However it is evident that the most important difference between *C. peltata* and *C. nummularia* lies in the structure of the shoots. An examination of both HARVEY's original types and others shows that *nummularia* always has this mode of growth and the accompanying structure of the shoots. That also an occasional crenulate disc can be met with seldom is true, but this contributes much less to its character than the mode of growth itself. The diameter of the assimilation discs varies, but can be said not to exceed 5 mm.

It must be observed that the big and splendid *C. macrodisca*, which is included by WEBER v. BOSSE as a variety of *peltata*, seems to have quite a different mode of growth. It has not procumbent branches with all the assimilation discs on one level, but it seems to correspond in its mode of growth with *peltata*. It also seems to grow in deeper water, since WEBER v. BOSSE mentions that she had "dredged" it at the mouth of the Maros river, which may point to the fact that it does not belong in every case to the uppermost part of the littoral zone.

Geographical distribution.—CEYLON : in the upper part of the littoral zone on rocks and amongst corals, in many places, at least on the south-west coast, but never occurring in large quantities ; thus, around Galle (in many places on the reef and rocks north-west of Victoria Park, but also amongst the Madrepores below the Utrecht Bastion, and on stones at Watering Point) ! INDIAN OCEAN ; AUSTRALIA ; PACIFIC (Friendly Islands).

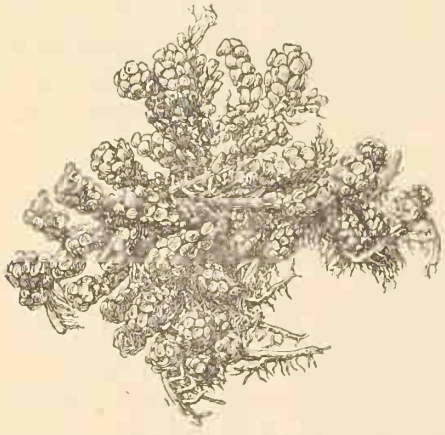

Fig. 37.—*C. imbricata* (KJELLM.). (1 × 1).

Fig. 38.—*C. imbricata* (KJELLM.) (1 × 1).

Fig. 39.—*C. imbricata* (KJELLM.) Flattened branchlets. (3 × 1.)

17.—**CAULERPA IMBRICATA** (KJELLMAN).

KJELLMAN in WITTROCK ET NORDSTEDT, Algæ Exsiccatæ No. 346 (sub nom. *Chauvinia imbricata*).

MURRAY, Catalogue p. 37.

SYN. *Caulerpa peltata* var. *typica f. imbricata* WEBER v. BOSSE, Monographie des Caulerpes: p. 375.

EXSICC. : WITTROCK ET NORDESTDT, Alg. Exsicc. No. 346.

f. minor. In all respects smaller and weaker. The size of the discs is upon an average 1 mm. in diameter (fig. 40).

f. mixta. The basal branchlets cylindrical ; the upper ones are typical imbricata—branchlets with the discs sharply defined from the stalk (fig. 42).

Under the name of *Chauvinia imbricata*, Professor KJELLMAN described and distributed in WITTROCK ET NORDSTEDT, Algæ exsiccatæ, No. 346, a little *Caulerpa* from Galle in Ceylon, collected during the visit of the "Vega" expedition in the month of December, 1879. This *Chauvinia imbricata* was afterwards included by WEBER v. BOSSE as a form under *C. peltata v. typica*. As its character

Kjellman accentuated that the generally shortish vertical axes are thickly clothed or perfectly covered from base to apex with branchlets, which are disciformly flattened at the apex with a diameter of 3-4 mm (fig. 39) This character is quite sufficient for distinguishing this little *Caulerpa*, which in Ceylon is rather common in the littoral zone. Figs. 37 and 38 show pictures of it. It is generally tufted very thickly and seen from above one sees nothing of such a one but the close vertical axes nearly quite covered with branchlets.

The origin of this form can be imagined in various ways. One is that it is derived from a *parvula* form (see below) in which the branches have been erected and have afterwards radiated, at the same time as the branchlets have become somewhat larger. Some transition forms (*f. minor*) between these two species—which have the mode of branching of *C. imbricata* and the size of the discs of *C. parvula*—also point to the fact that such a development must not be considered as only a hypothesis and without any real foundation. As a matter of fact, these forms also occur in almost the same localities in the upper part of the littoral zone.

But *C. imbricata* can be imagined also to have originated in another way. If we study its organization we might give this as its characterization : *C. imbricata* is a somewhat dwarfed *C. uvifera* in which the branchlets have become somewhat disciformly flattened. In reality forms of this kind do occur which derive directly from *uvifera* by change of spherical branchlets to flattened ones. *C. uvifera f. planiuscula* is such a form. Moreover, there are some transition forms collected by KJELLMAN at Galle and by myself at Jaffna, which point to a relationship with *peltata* main form (fig. 41). If in such a one the vertical branches are shortened and get a more one-sided direction, at the same time as the discs grow smaller and closer, there then arises an *imbricata* form. Hence it seems probable that such a form could be derived from either the one or the other.

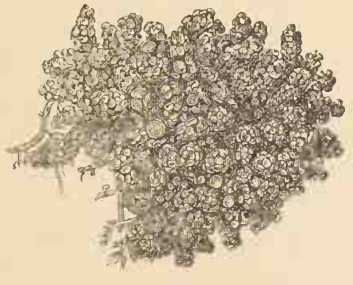

Fig. 40.—*C. imbricata* (KJELLM.) *f. minor* n. f. (1 × 1).

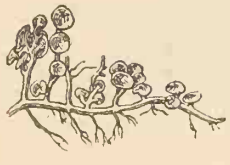

Fig. 41.—*C. imbricata* (KJELLM.) f. *ad peltatam*. (1 × 1).

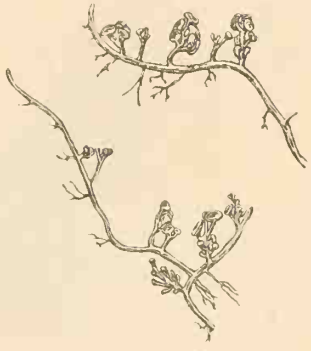

Fig. 42.—*C. imbricata* (KJELLM) f. *mixta* n. f. (1 × 1).

It is rather remarkable that variations of *C. imbricata* are to be found which are quite analogous with *C. Chemnitzia*. Fig. 42 shows such a form, for which I propose the name *mixta*. The basal branchlets are cylindical, about 3 mm. in length and only 1½ mm. in breadth, and at the apex abruptly cut off, as if truncated, just as in *Chemnitzia*. Somewhat below the middle of the vertical axis commence the typical *imbricata* branchlets—with the discs sharply defined from the stalk—and continue up towards the apex. This form, however, is not *C. Chemnitzia*, for the latter has not only basal branches which are cylindrical, but its upper branches increase only slowly in breadth and are almost trumpet-shaped. (*cf.* fig. 27), and often also the upper branchlets are spherically enlarged as in *racemosa*. WEBER v. BOSSE had also placed *Chemnitzia* under this species, but with the observation that it is an intermediary form between *racemosa* and *peltata*. In the form *mixta* the basal branchlets are cylindrical as in *Chemnitzia*, but the upper branchlets are typical *imbricata* branches. The mode of growth of this form in the upper littoral zone corresponds also in every respect with that of *C. imbricata*.

By reason of *C. imbricata* in Ceylon seeming to be a form or race equally distinguishable from the remaining *peltata* forms, as are *nummularia* and *typica* (WEBER v. BOSSE), I think there is little

justification for placing it only as a form under *peltata* var. *typica*, as WEBER v. BOSSE has done. Var. *nummularia*, *exigua*, &c. should by equal right be included as forms, but WEBER v. BOSSE has given these a systematically higher rank in calling them "varieties," *i.e.*, equal with var. *typica*.

My contention is strengthened by the fact that *C. imbricata* itself shows some variations that could also be classed together. And if we are to place it under any other form it could as well be classed under the small *nummularia* forms, as for instance *f. parvula*, as under any of the others. The plausibility is equally great in either case.

Geographical distribution.—CEYLON: in the upper part of the littoral zone amongst rocks and corals, rather common; Matara! Galle (*f. minor*), in many places on the reef (as below the Sailors' Bastion, Star Bastion, Aeolus Bastion, Pigeon Island)! Ambalangoda! Jaffna! SOUTH INDIA: Paumben (*f. minor*, *f. mixta*)!

18.—**CAULERPA PARVULA,** n. sp.

The horizontal axes creeping with their side axes mostly procumbent. The whole plant thus forms mat-like tufts with the assimilation system on one level as in *C. nummularia*. The assimilation discs very small, about 1 mm., never exceeding 2 mm.

Under this name I will distinguish a very weak small form in the *peltata* group which I have observed in several places in the district investigated, and which is figured in figs. 43, 44. The mode of growth approaches that of *C. nummularia* in being richly tufted with the branches procumbent, and all the very small assimilation discs about on the same level, agglomerated together.

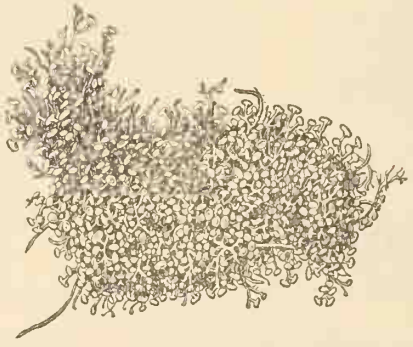

Fig. 43.—*C. parvula* n. sp. (1 × 1).

Fig. 44.—*C. parvula* n. sp. (1 × 1).

To judge from the very small dimensions of this plant—the diameter of the assimilation disc about 1 mm. and never exceeding 2 mm.—one might think it to be closely allied to *f. exigua*, WEBER v. BOSSE (*loc. cit.* p. 377, fig. 11, Pl. XXXI.); but the character distinguishing this latter—viz., its assimilation discs as if perfoliate, and situated as it were in one storey above the other—is entirely lacking. But as the assimilation discs are all in their dimensions rather constant, and the plant in other respects as far as its habitat is concerned, makes an impression quite different from *C. nummularia*, it seems to me to be distinguished as a special form. It forms, one may say, a transition species from the typical *nummularia* to the *imbricata* series. For if the side branches, instead of being procumbent were to grow upwards, and if, together with this, the branching were to become radiate, we should have *C. imbricata*.

At Paumben, in the Island of Rameswaram, I have also collected some transition forms (*C. imbricata*, *f. minor*, fig. 40) between this form and *C. imbricata*.

Geographical distribution.—CEYLON: Rather locally in rock-pools at Beruwala, and at Paumben in the Island of Rameswaram (SOUTH INDIA)!

19.—**CAULERPA LONGISTIPITATA** (Weber v. Bosse).

Syn. *C. lentillifera* (J. G. Agardh) Weber v. Bosse, var. *longistipitata* Weber v. Bosse in Th. Reinbold's Marine Algæ in Flora of Koh Chang by Johs. Schmidt, Part IV., p. 105.

The horizontal axis extended, with rather few vertical axes (=assimilators); these are simple, only exceptionally branched, with the branchlets or pinnules generally opposite in two rows, but sometimes also projecting in all directions. The branchlets at the top provided with a little ball-shaped vesicle of about 1-2 mm. in diameter, bounded by a remarkable constriction. The basal part of the same length or shorter than the vesicle. The diameter of the vertical axis commonly not exceeding twice that of the branchlets.

I have observed this *Caulerpa* in the more sheltered places of the littoral zone at the islands at Paumben Pass, especially on stones, with its long creeping rhizomes adhering thereto or entangled in other algæ; sometimes it also occurred drifting and entangled in algæ which had broken loose.

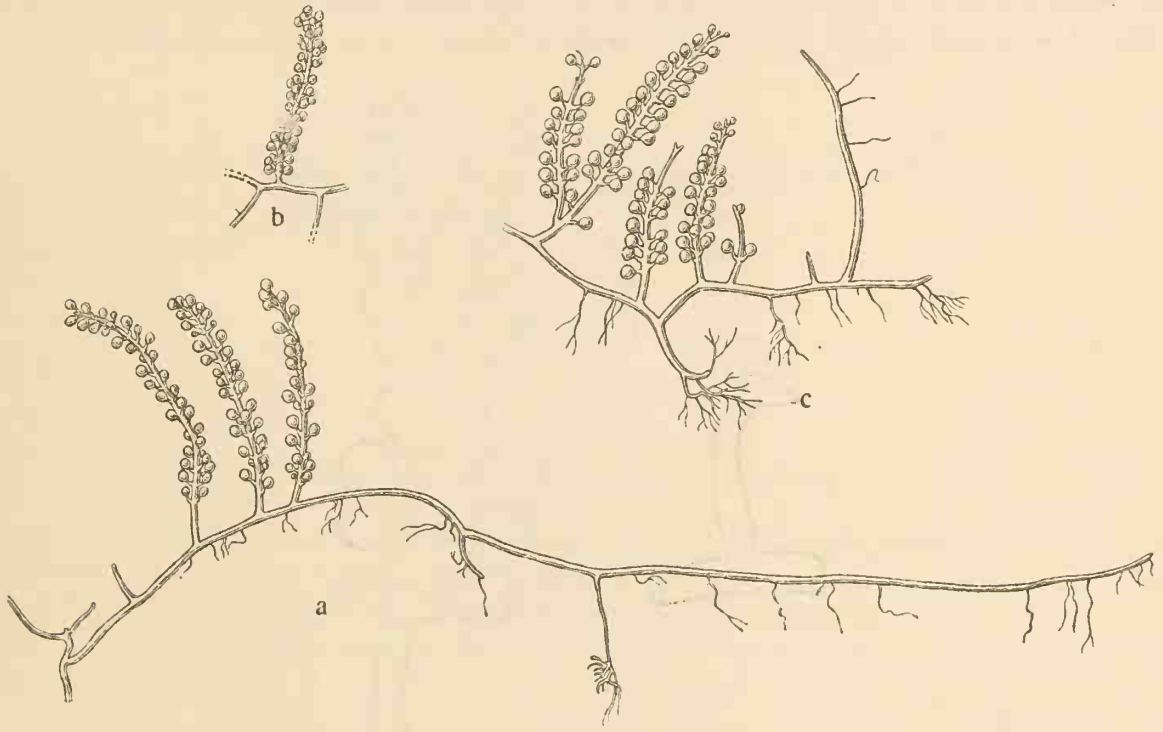

Fig. 45.—*C. longistipitata* (W. v. B.). *b* shows an assimilator with the branchlets in many rows. (1 × 1).

This *Caulerpa*, which I have placed as a species of its own, was first described by Weber v. Bosse as a variety of *C. lentillifera* in Major Th. Reinbold's paper on the algæ from Koh Chang in the Gulf of Siam collected by Dr. Johs. Schmidt. I have had an opportunity of examining these type specimens and I can assert their conformity to the Ceylon specimens. That Weber v. Bosse, with such limited material, was presumably unwilling to create a new species among the Caulerpas is comprehensible when one thinks of the great multiformity of these organisms, and the more so as this author is inclined to form wide-embracing species (so wide-embracing as far as *lentillifera* is concerned, that even a form so different as *C. Kilneri* is included). But my study of this plant from a somewhat richer material from Paumben showed that it is in the main constant, and it seems to me to be rather well characterized and distinct from *C. lentillifera*, with which it is most closely allied.

C. longistipitata differs from *C. lentillifera*, as Weber v. Bosse points out, in the small number of the rows of pinnules (fig. 45). This may vary a little, however, but the predominant number of vertical

axes have the pinnules in opposite order (fig. 46 *b*.), and this gives the plant a rather characteristic habit. Its next important character is the relatively considerable length of the pinnule in comparison with the ball-shaped vesicle, which last is also greater than in *C. lentillifera* in general. In *C. longistipitata* its diameter is rather above than below 1½ mm., and often reaches as much as 2 mm. The length of the pinnules often reaches the same measure, *i. e.*, they are also as long as the vesicles, but in every case always longer than half their diameter. Finally, we must point out that the vertical axes are very weak in comparison with the pinnules, and only about twice as broad, and often not even that, but less. This seems to me to be worthy of accentuating, because it has not been pointed out by Weber v. Bosse, who, on the contrary (*loc. cit.* p. 382), is of opinion that this is a very subordinate character depending only on the age of the plant.

An examination of fig. 1 *a*, PL. XXXIV. in Weber v. Bosse's Monograph shows just as the study of the original specimen itself (No. 16.851) in Agardh's Herbarium, that *C. lentillifera*, J. G. Agardh, has relatively thicker vertical axes and smaller vesicles, whereas in *C. longistipitata* the axis in its breadth is most often below or at least never above the diameter of the vesicles (figs. 45, 46). In this respect I have never seen any variation in *C. longistipitata*.

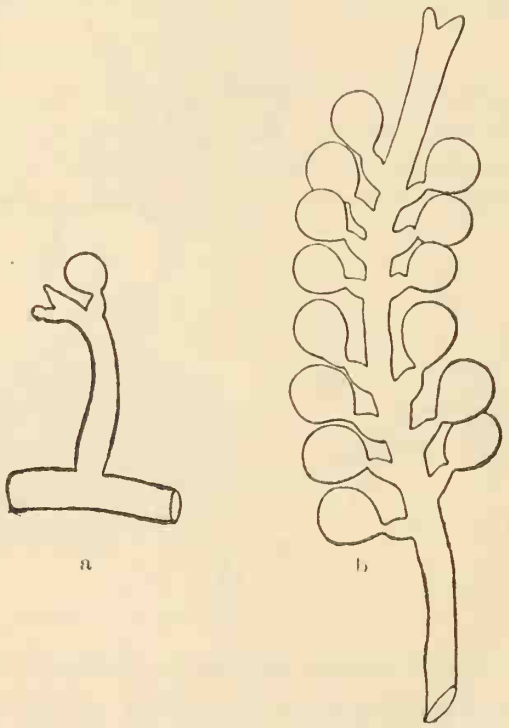

Fig. 46.—*C. longistipitata* (W. v. B.). (*a* 5 × 1, *b* 4 × 1).

For this reason it seems to me to be fully justified if we consider *C. longistipitata* as a distinct elementary species. My opinion here is supported by the fact that in the district where this species occurs, in the islands in the north between India and Ceylon, it showed itself very uniform, nor are any real *lentillifera* forms known from Ceylon. Its geographical distribution also seems to strengthen this view. *C. lentillifera*, J. G. Agardh, is only known from the Red Sea and the western parts of the Indian Ocean (Madagascar), that is, it has *Western* distribution; *C. longistipitata*, on the other hand, is known from the Gulf of Mannar and the Gulf of Siam in the north, to New Guinea in the south, consequently it has a more *Eastern* distribution; *C. Kilneri*, finally, only from the Timor Sea.

Geographical Distribution.—South India: Paumben Pass! Pacific (Gulf of Siam).

20.—**CAULERPA SEDOIDES** (R. Brown) C. Agardh.

C. Agardh, Spec. Algarum, p. 438.
J. G. Agardh, Till. Algernes. Systematik 1., p. 39.
Weber v. Bosse, Monographie des Caulerpes, p. 387.

f. crassicaulis, J. G. Agardh, loc. cit. p. 40.

f. mixta. In all respects smaller and weaker. The horizontal axis about 1 mm. in diameter. The vesicles (branchlets), ·5 to 2 mm., commonly 1 mm. in diameter, of different kinds, viz., (1) sessile or pedunculate with spherical tops and evident constrictions; (2) sessile with somewhat pear-formed tops; (3) long, extended, cylindrical.

I have found *C. sedoides f. crassicaulis* in Ceylon in several specimens from Matara, Dondra Head, and Weligama on the south coast (fig. 47). Almost all correspond well with Agardhs's *f. crassicaulis*. Thus the vesicles are, as a rule, always spherical, there are no joints on the main axis, and the closely set branchlets stick out in all directions around the main axis. But, on the other hand, the

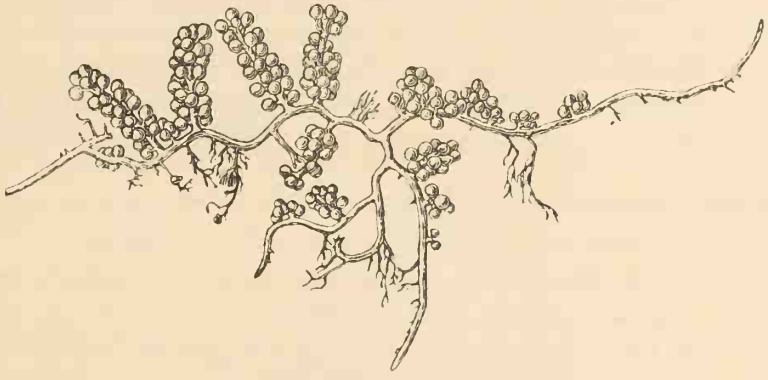

Fig. 47.—*C. sedoides* (R. Br.) C. Ag. *f. crassicaulis* J. G. Ag. (1 × 1).

vesicles are sometimes provided with a very short but distinct stalk (fig. 48), and this seems also to be the case with Agardh's own type-specimens, a character again shown in some high-grown *crassicaulis* forms (in the Herbarium of the R. Riksmuseum in Stockholm) from Torres Strait (Aug. 1846). Also Weber v. Bosse speaks about (*loc. cit.* p. 388) a *Caulerpa* from Upola, in which some branchlets are

Fig. 48.—*C. sedoides* (R. Br.) C. Ag. *f. crassicaulis* J. G. Ag. (2 × 1).

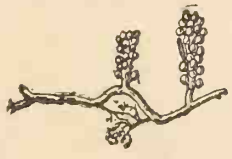

Fig. 49.—*C. sedoides* (R. Br.) C. Ag. *f. mixta n. f.* (1 × 1).

Fig. 50.—*C. sedoides* (R. Br.) C. Ag. *f. mixta n. f.* (2 × 1).

pedunculate, reminding one almost of *C. racemosa v. clavifera*, from which it is however distinct by its constriction. Both in Matara and Weligama the *f. crassicaulis* showed itself very uniform and scarcely variable and gave the impression of being a distinct race.

In the island of Jaffna in the north of Ceylon I found some peculiar specimens of a very exceptional appearance. It is these that I have described as *f. mixta* (figs. 49, 50). In all respects it is more slender and weaker than the preceding form. In addition to small pedunculated vesicles with constrictions below the top, it has pear-shaped branchlets, clearly indicating opposite arrangement just as in *f. geminata*, HARV.; finally, and this is the most characteristic feature, some few branchlets grow out cylindrically to a breadth of 3 mm., and show themselves to be of the same shape as *C. ambigua* OKAMURA (*cf.* OKAMURA. "Algæ from Ogasawara-jima." PI. 1, figs. 4, 6, 7).

Geographical distribution.—CEYLON: Dondra Head! Matara! Weligama (*f. crassicaulis*)! in the last named place at a depth of about 1½ to 2 metres (at low-water) inside the reef together with *C. sertularioides* and *C. taxifolia*; in the other places in the upper littoral zone; Jaffna (*f. mixta*)! INDIAN OCEAN; PACIFIC OCEAN.

C. sedoides in a wide sense is known from Australia, New Zealand, and Tasmania in the south. From Ceylon, the Gulf of Siam (SCHMIDT) in the north, and to the Friendly Islands in the east The different forms seem to have their different limited districts: thus, *f. tasmanica* and *geminata* have exclusively southern distribution (Australia and Tasmania), whereas *f. crassicaulis* has exclusively northern, true tropic distribution (the tropical coast of Australia, Ceylon to Friendly Is.). This possibly points to the fact that these forms have rather the character of different races or elementary species, an inference that is furthermore strengthened by the fact that, as I have mentioned above, *f. crassicaulis* in Ceylon is constant and uniform. Against this, *f. mixta* seems more local, and, as I have above tried to show, its peculiar branching may probably be explained as a kind of atavistic bud-variation.

21.—**CAULERPA FERGUSONII** (MURRAY).

MURRAY. On some new species of Caulerpa, p. 212, pl. 53, fig. 1.
WEBER v. BOSSE, Monographie des Caulerpes, p. 389 (*sub nom. C. Fergusoni*).
EXSICC.: FERGUSON, Ceylon Algæ, No. 415.

This *Caulerpa*, only known from Ceylon, I have observed once at Paumben Pass, and there very scantily, growing on mud or slime together with *C. longistipitata* and *Enalus acoroides*. To the description of this plant, which we owe to MURRAY, the following may be added:—

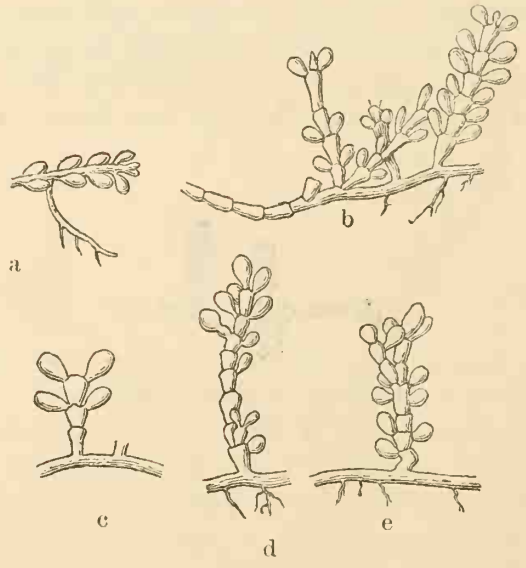

Fig. 51.—*C. Fergusonii*, MURR. (1 × 1).

It does not seem to be uncommon for the branched stem, when situated horizontally, to form coarse roots downwards and jointed side branches upwards. Fig. 51 *a* and fig. 51 *b* show this case,

which is far from being rare among *Caulerpas*, and which seems to occur also in the related *C. cactoides*. (*cf.* MURRAY, *loc. cit.* pl. 52, fig. 8, and WEBER v. BOSSE, *loc. cit.* p. 391). Moreover it seems to happen, though more rarely, that the vertical axes are jointed right up from the base without any branchlets being formed from the joints at the base (fig. 51 *c*). It has been pointed out that the difference between *Fergusonii* and *cactoides* may consist in the former plant being only jointed at the place where the side branchlets are formed, as against *cactoides*, which is jointed the whole way up, though the base seems to lack side branchlets for a part of the way up. This character, though right in the main, does not always hold good, and sometimes one can observe at the base (fig. 51 *c*) some evident joints without any side branchlets at all.

Just as in *C. cactoides*, *C. Fergusonii* can also have regeneration branches, *i.e.*, may repeat the branching of the mother axis. A branchlet in fig. 51 *d* seems to branch ; it looks as if the branchlet itself were jointed. In other cases the branch-formation takes place as follows : between two branchlets the growth of a side axis takes place. Hereby the branches become verticile (fig. 51 *e*), a case which WEBER v. BOSSE has also observed in *C. cactoides*, loc. cit. p. 391. When such a side branch is formed between two branchlets it is, to begin with, quite similar to these, and all three form a whorl of branchlets. By this a formation arises which resembles the verticile branches in the fossil *C. Carruthersii*. It is therefore remarkable that also in living Caulerpas verticile branches may be formed, though it must be considered to be a rare occurrence. From a phylogenetic point of view it is interesting in any case.

From what has been stated above it seems that this form of *C. Fergusonii* is much more closely related to *C. cactoides* than to *C. sedoides*.

Geographical distribution.—CEYLON (FERGUSON). SOUTH INDIA : Paumben Pass, in the littoral zone, in shallow water on mud, together with *Enalus acoroides* !

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